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Levee Analysis and Design for Proposed Missouri Refining Co. Petroleum Refinery Site.

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Geological Engineering Senior Design Project

Levee analysis and design for proposed Missouri
Refining Co. petroleum refinery site.

Matthew Carns

12/2/2010

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A. Introduction

A.1. Problem Definition

This report is intended to cover the design and construction of a levee around the proposed Missouri Refining Co. petroleum refinery, see Figure 1 for location. The location is near the confluence of the Yellowstone and Missouri Rivers in Williams County, North Dakota. The recent success in extracting unconventional petroleum reserves in the Williston Basin has led Missouri Refining to consider building the refinery in the area.

With the location so close to the rivers it has been determined that a permanent levee structure is needed to protect the site from seasonal flooding. The levee will encompass the site and removable flood walls will be utilized where access roads are needed.

The soil composition and stratigraphy were found to be suitable for levee construction. The borrow material will be excavated from the site and the undisturbed soil will make a solid foundation for the levee.

To construct a design the local conditions and how they will affect the site will be evaluated. These conditions include historical flood levels, soil characteristics, and climatic influences. A field investigation of the proposed site will be performed so field observations and soil samples can be collected. Laboratory testing will provide the soil specifications necessary for the levee design.



Figure 1: Location of Proposed Levee

A.2. Background

The Yellowstone and Missouri Rivers converge 2 miles north of the proposed location. The Yellowstone flows northward along the eastern side of the site and the Missouri flows eastward along the northern side of the site. The Yellowstone River is closer to the proposed site but a high flood stage in either river could lead to overland flooding of the site.

The proposed location is in an alluvial flood plain. The strata vary from sand to silt to clay and are layered throughout the upper 5 feet. Below this level the composition is unknown but it is assumed to also be an alluvial deposit with similar characteristics.

Flooding history of the location will be researched to determine an optimal levee height to protect the site. This history is limited as the Fort Peck Dam located upstream on the Missouri was completed in 1940 and the Garrison Dam located downstream was completed in 1953. These two dams were constructed in part to control river levels and lessen flood intensity. Even with the dams, the rivers have exceeded flood stage numerous times.

B. Preliminary Analysis

B.1. Design Constraints

The area that Missouri Refining wants to protect requires a rectangular levee. The dimensions are 5280 feet by 2640 feet yielding a total levee length of 15,840 feet. These

dimensions are measured along the edge of the landside slope. The area to be enclosed measures approximately 320 acres.

The site is in the flood plain of both the Yellowstone and Missouri Rivers. The upper soil strata are comprised of mainly alluvial silts and clays. The upper 60 inches of soil are going to be the most critical to the design so most of the analysis will be concerned with them. On most of the site the upper soil is silty clay (CH Unified classification) with some sandy loam areas (NRCS).

B.2. Design Options

Later analysis and testing has determined the best design for the levee project. The United States Army Corps of Engineers (USACE) manual EM 1110-2-1913 “Engineering and Design – Design and Construction of Levees” was used as a guideline for the design process. Erosional factors, slope and foundation stability, seepage control, and possible settlement issues were also taken into consideration.

The dimensions and components of the levee were also determined after finding soil specifications and performing computer modeling using the Rocscience software. Components such as toe drains, drainage ditches, toe trenches, landside berms, drainage layers and a semi-permeable core were analyzed and implemented if deemed necessary.

The construction of the levee was assessed and broken down into stages. The techniques that will be used in the construction were also be analyzed. Vegetative cover was considered and implemented as well where needed.

B.3. Levee Height Analysis

The ground level of the location is 1880 ft MSL. The datum river level for the Yellowstone near the site is 1860.54 ft MSL. There are no continuous river level/flow monitors at the proposed location so the flood levels and stages were taken from the closest USGS station. This station is located near Cartwright, ND and is approximately 5.5 miles upstream on the Yellowstone River. The USGS station number is 06329610.

To find the elevation data for the river at the site, information was used from the Cartwright, ND USGS station and the Williston, ND USGS station. The calculated gage datum (1796.42 ft MSL) corresponds with the Cartwright, ND gage datum so the stage at that station can be used exactly with the site gage. Daily gage readings taken by the USGS from 1959 to 2009 were used to construct a flood frequency diagram to determine the stage of a 100 year flood, see Appendix C.

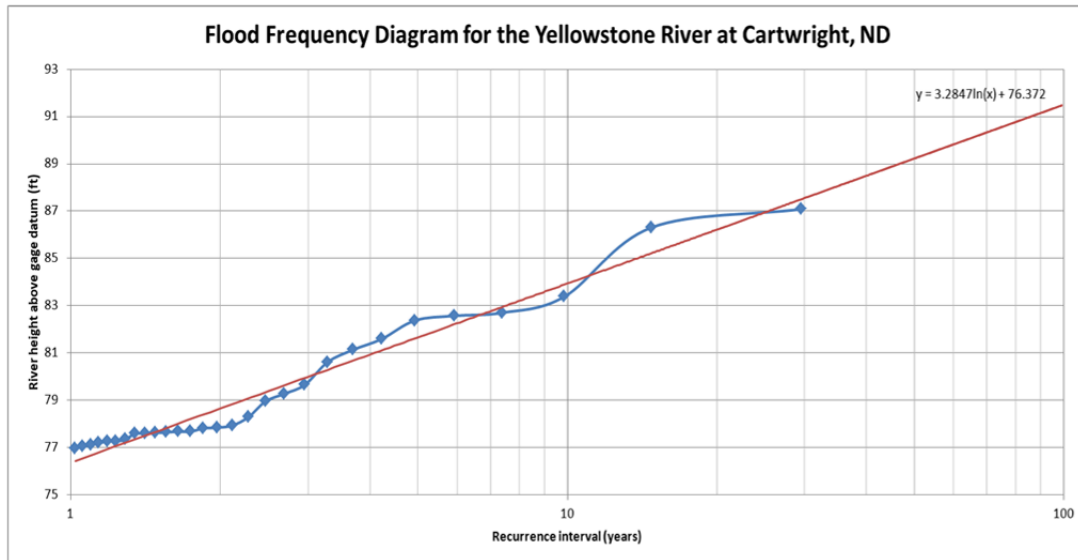


Figure 2: Flood Frequency Diagram

The recurrence interval for each value was found and values below 1 year were disregarded. Figure 2 shows the plot of the gage height and recurrence interval on a log scale. A best-fit logarithmic line was created and from that the following equation was found.

$$y(\text{gage height in ft}) = 3.2847 \cdot \ln(\text{time}) + 76.372$$

This equation yields a gage height for a 100 year flood of 91.5 ft. The actual elevation of this stage at the site would be 1887.92 ft MSL or 27.38 ft above the datum river elevation.

Thus a 100 year flood would cover the site in almost 8 feet of water (site elevation of 1800 ft MSL). To offer protection against possible future high flood levels the levee will be constructed to protect against a flood elevation of 1888 ft MSL. The minimum amount of freeboard required by the USACE is 3 feet. The common allowance for subsidence in semi-compacted levees of 10% will be used. The tentative top of the levee is 1892.1 feet MSL

factoring in a USACE typical subsidence value of 10%. The height of the levee is going to be 12.1 feet above the ground surface.

C. Laboratory Test Results

C.1. Field Observations

The land that the site is to be constructed on is primarily used for agriculture. There are a few petroleum production sites and homes in the nearby vicinity. Roads are already in place for access to the site although they will probably have to be enlarged for heavier traffic. The vegetative cover in the area is limited to agricultural fields and some stands of trees near the rivers. The trees are far enough away from the site to not pose a problem with piping.

Field samples were collected from a single bore hole along the eastern side of the site and from a shallow hole on the northwest corner of the site. Appendix A shows the location of the bore hole (B-1) which was dug to a depth of 6 feet and the location of the other sample hole. Samples (S-1, S-2, S-3, S-4, S-5, and S-6) were taken at regular intervals and used for analysis. The location of the bore hole is at the following coordinates (North 47.94629, West 103.96830).

The samples were immediately logged for initial soil characteristics and then bagged for lab work. Shelby tube samples (ST-1, ST-2, and ST-3) were collected from 3 intervals and they were used to determine the shear strength and compressibility of the soil. The shear strength

was found using a handheld vane device and the compressibility was found using a pocket penetrometer.

C.2. Grain Size Analysis

Soil characteristics of the area are a vital part of the design of the levee. The location of the borrow areas for the material to construct the levee is the first and foremost issue. The intended borrow pits are around the perimeter of the levee. This will reduce the amount of material hauling and allow for quicker and easier construction. Some sections around the levee will not be excavated for borrow materials to facilitate road construction and other utilities/infrastructure.

Six samples were used for grain size analysis. These samples are from the borehole that was dug on the east side of the site and they are from various levels down the hole. Each sample was sieved initially and then a hydrometer test was performed. The results of these tests are found in Appendix D.

The hydraulic conductivities (K) were found using the grain size distribution graphs. Two methods of calculating them were used. The primary one is the Alyamani and Sen Method. The d_{50} value is the grain size at which 50% of the sample is finer and the d_{10} is the grain size at which 10% is finer. The I_0 is the x-intercept of a line drawn between the d_{50} and d_{10} values.

$$K = 1300 * [I_0 + .025(d_{50} - d_{10})]^2$$

The Hazen Method was used as a check for the answers from the initial method since it is the most common form of calculating the hydraulic conductivity. The d_{10} value in this equation is also the grain size at which 10% of the sample is finer and the c value is a constant defined by Hazen to be approximately 1.1.

$$K = c * (d_{10})^2$$

The results of the six individual hydraulic conductivity calculations were averaged using the geometric mean method. This resulted in a value of $K = 1.56^{-5}$ cm/sec, which is typical of silty clay soil.

D. Final Design Analysis

D.1. Computer Modeling

The final design was selected using computer modeling to simulate the design. The Rocscience Slide 6.0 software allows the calculation of the piezometric surface within the levee. The location of the piezometric surface determines whether the structure is sufficient enough to withstand the 100 year flood event. If water flows out of the landside edge of the levee it can cause failure so the piezometric surface has to drop far enough to prevent this.

The model was constructed using the soil properties determined in the laboratory testing of the samples collected in the field. The most important of these was the hydraulic

conductivity which was averaged between the six values determined experimentally from field samples. The hydraulic conductivity is the main determinant for the water flow through the levee and thus controls the majority of the design.

The slope of the levee sides that is best suited to this project is 33.33 degrees or 1:3. According to the Corps of Engineers manual this allows for vegetation maintenance and ease of construction. The width of the crest was set at 12 feet which allows vehicle travel for inspection and maintenance.

The initial analysis was done for a semi-compacted levee using the hydraulic conductivity of the underlying soil, which is the same as the borrow material. The result of this analysis was that another structure would have to be added to the levee to facilitate the lowering of the piezometric surface to a safe level.

An analysis was done with a toe drain under the landside slope of the levee. The toe drain measured 1.7 feet thick and 42 feet long. It was placed just below ground level from 25.54 feet from the landside edge of the levee and extended along the base of the levee to 16.41 feet past the landside edge into the protected area. A typical clean sand was the material selected to be used in the analysis of the toe drain. The hydraulic conductivity of a typical sand is approximately $K = 1 \times 10^{-1}$ cm/sec. The result of this analysis was successful and this design would meet the criteria set forth earlier in the report.

E. Work Plan for Final Design

E.1. Plans and Specifications

E.1.A. Levee

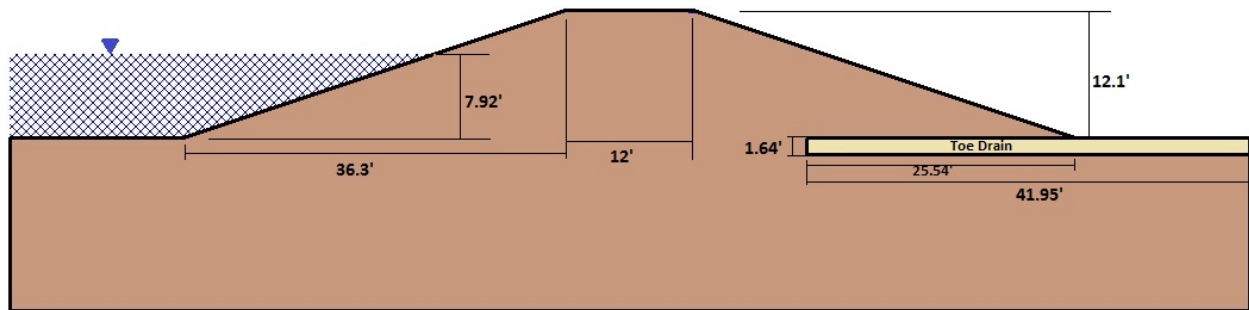


Figure 3: Cross Section of Levee

The final cross section for the levee is shown in Fig. 2. These dimensions were chosen because they meet the design constraints and requirements, they are practical and feasible, and they follow the guidelines set out by the USACE in the Engineering Manual EM 1110-2-1913.

The final overhead/map view of the levee is shown in Figure 1. These dimensions were chosen because they also meet the design constraints and requirements, they are practical and feasible, and they follow the guidelines set out by the USACE in the Engineering Manual EM 1110-2-1913.

E.1.B. Borrow Areas

The borrow area for the levee construction will be located around the entire levee. It will begin 50 feet from the base of the riverside toe of the levee, the USACE standard minimum berm between the borrow pit and the levee toe is 40 feet. Where the access roads are to enter the levee there will be traverse areas where there is no excavation done for borrow materials. The traverse width will need to be at the minimum the width of the access road and a stable slope on either side into the borrow pits.

The depth of the borrow pits will be 5 feet and the slope along the edge will be about 10 degrees or 1:6. To account for compaction the volume of the borrow pits will be approximately 125% of the volume needed for the construction of the levee. This total borrow pit volume is $1.0158 \times 10^7 \text{ ft}^3$ or $3.7622 \times 10^5 \text{ yd}^3$. If the pit is made 120 feet wide and 5 feet deep around the levee there will be sufficient building material. Appendix F contains the volumetric calculations for the borrow areas.

The volume of material needed for the toe drain is $1.0853 \times 10^6 \text{ ft}^3$. The source for the toe drain material will need further investigation. Most of the soils near the levee location are silt to clay in composition and have too small of a hydraulic conductivity to be of use. One location that was found 1.5 miles southwest of the site may be considered a source pending field investigation and lab work on the soil. The NRCS classifies the soil as the Seroco-Lohler complex and on the soil map its symbol is 10D. Appendix B has the location and info on this soil and Appendix F has the volumetric calculations.

E.2. Construction Cost Estimates and Work Schedule

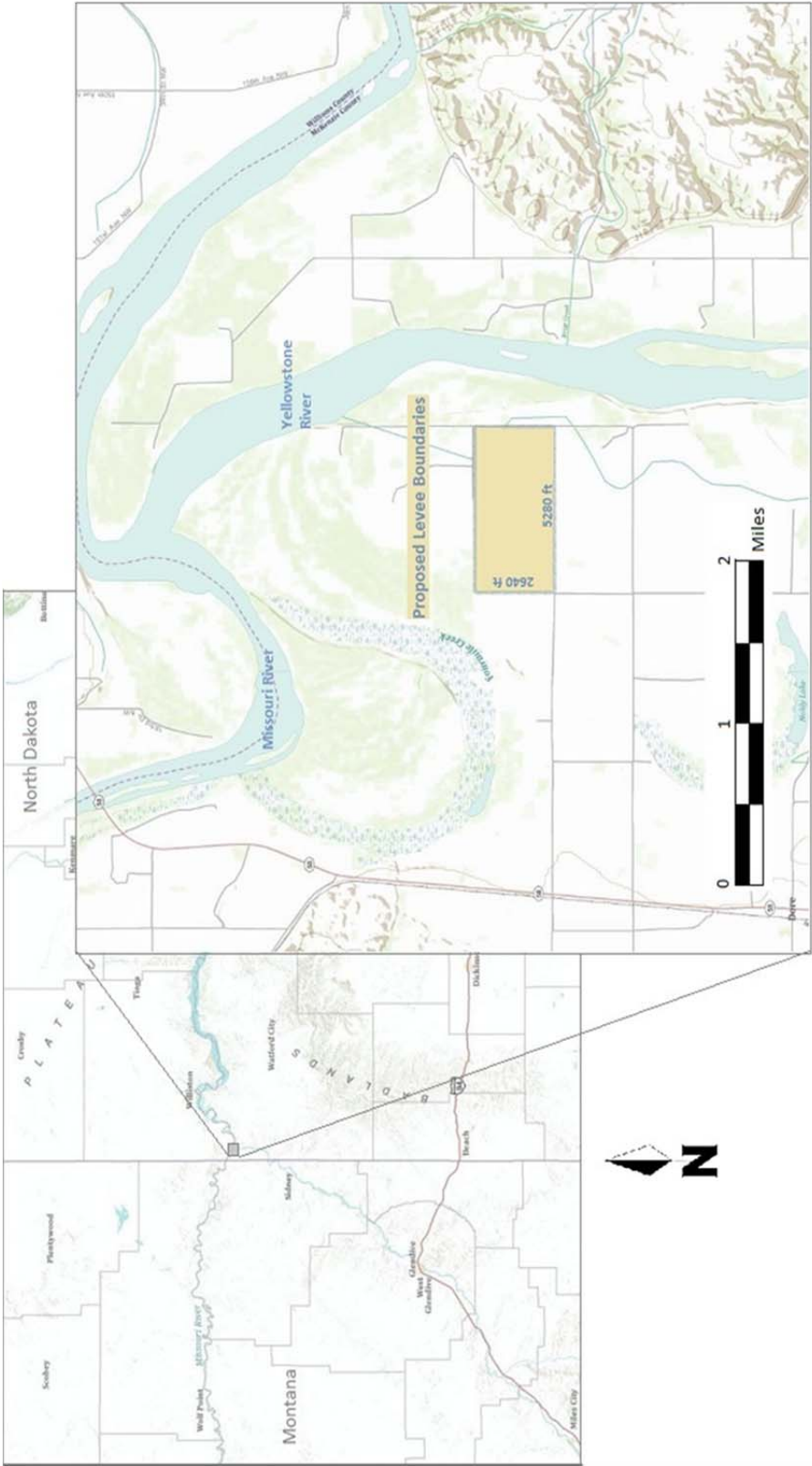
The R.S. Means construction costing book was used to formulate the estimates for the cost of the levee and the work schedule. Using the design criteria selected above and the Means book an estimate of \$1.67 million was derived, see Appendix G for a breakdown on the costs.

This estimate includes all of the site work from stripping the ground to seeding vegetation onto the finished levee and borrow areas. Built into this estimate is a 25% increase for inflation (1997 costing values were used) and other contingencies. Other factors that may influence the estimate are further soil testing and engineering analysis/planning.

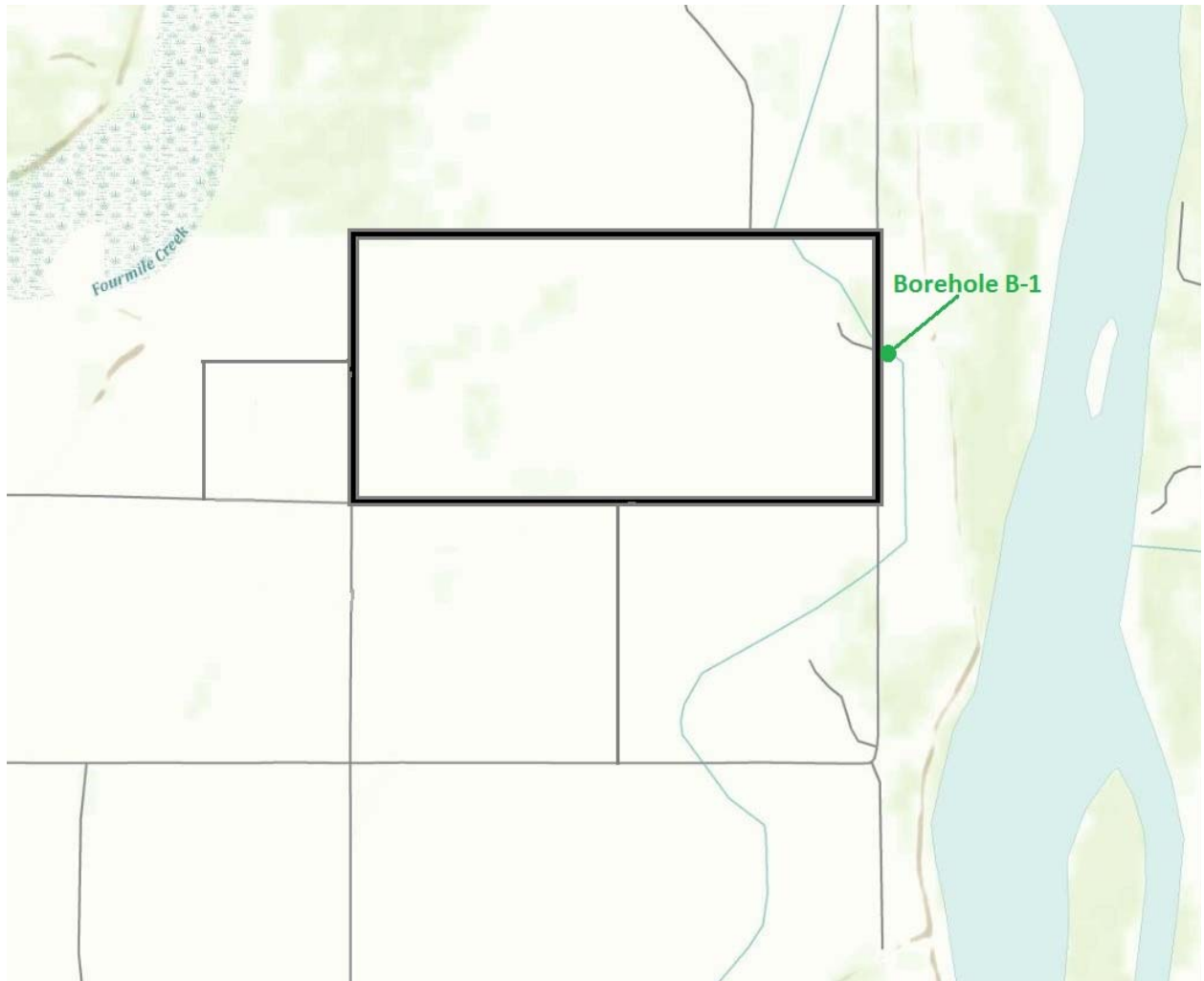
The work schedule was determined using the Means book and the calculations for the various parameters of the levee and borrow areas. A start date of May 1, 2011 gives a completion date of August 19, 2011. Appendix G contains more information on the work schedule.

Appendix A

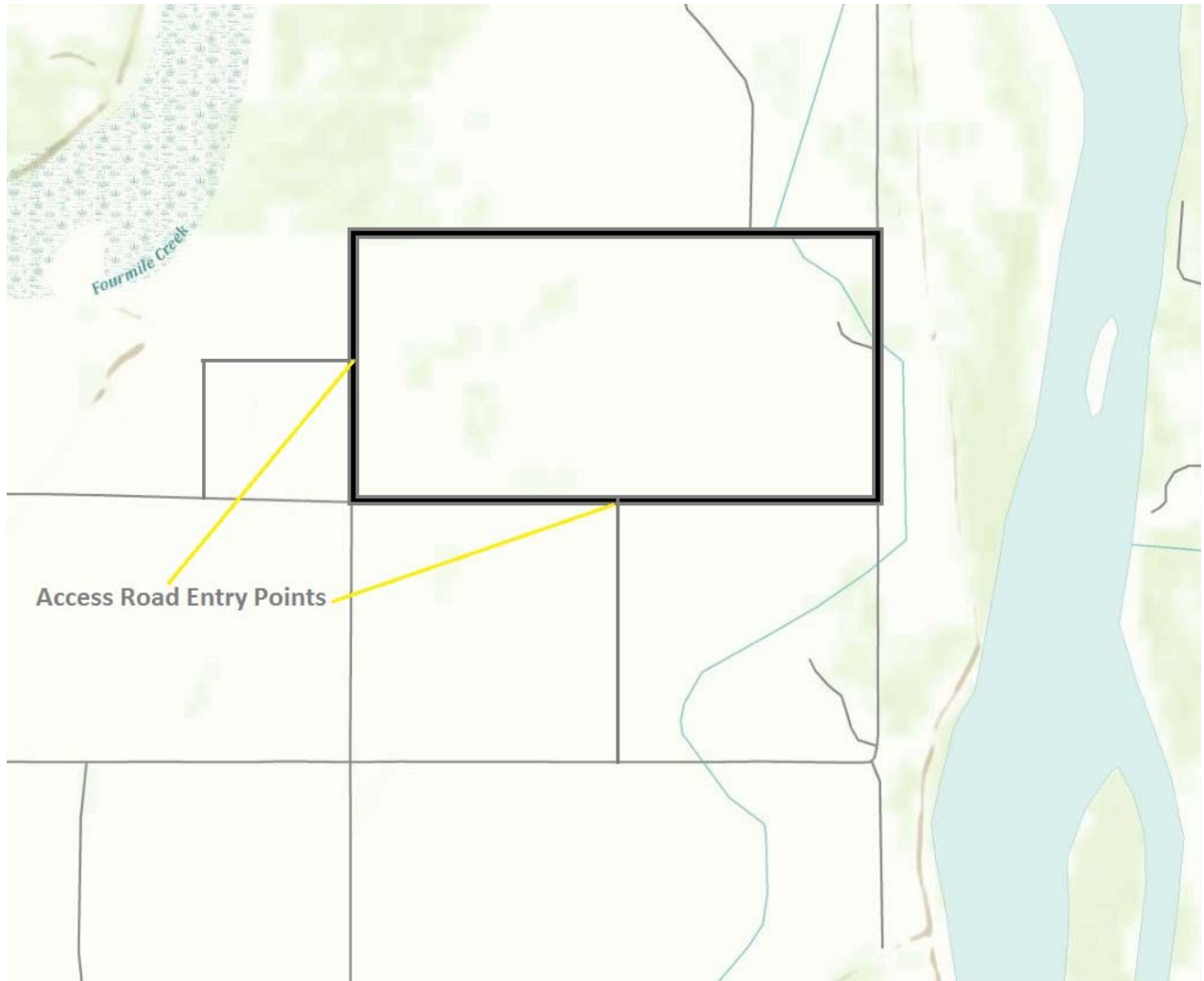
Map of Proposed Levee Location



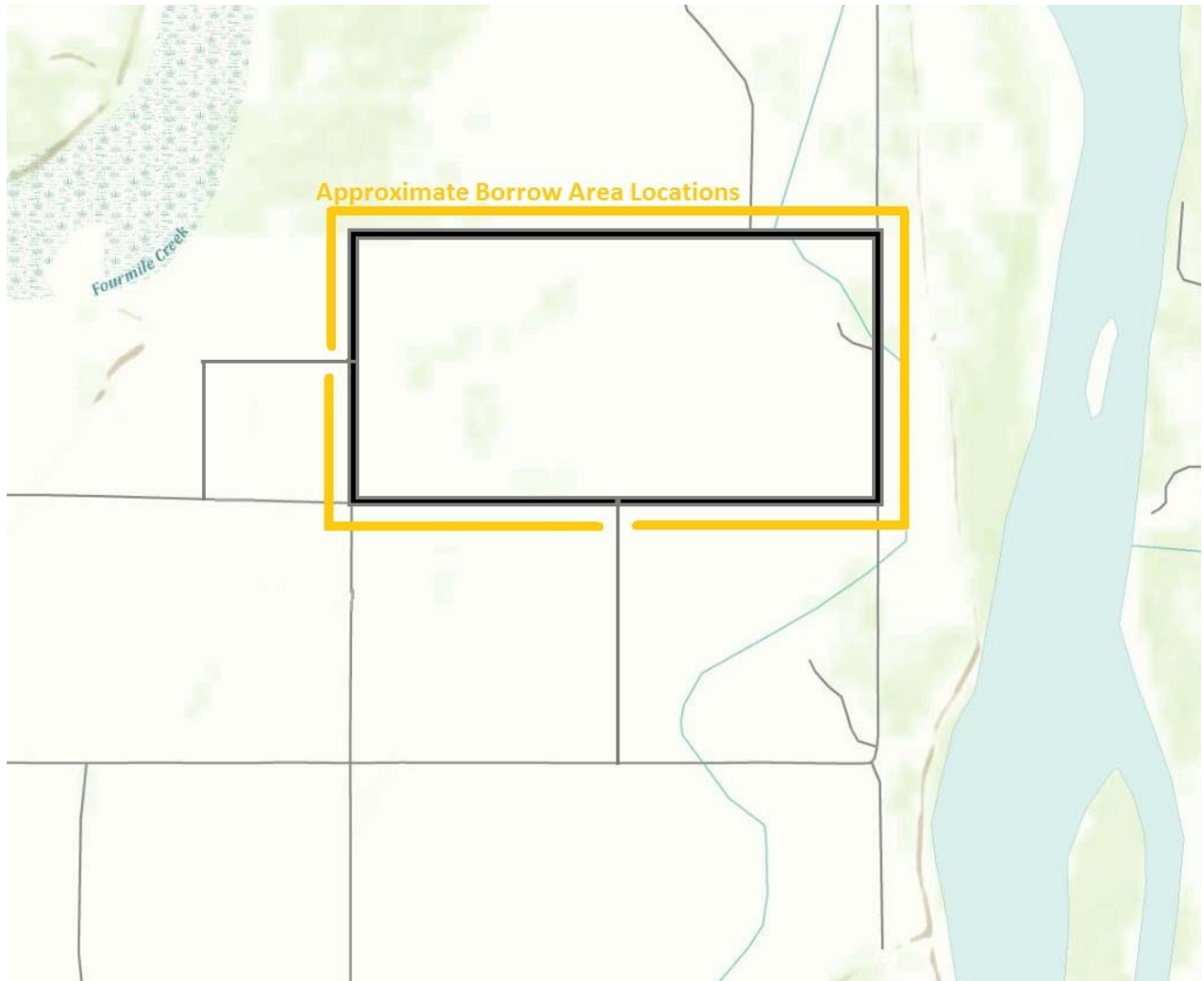
Map of Bore Hole (B-1) Location



Map of Access Road Locations



Map of Borrow Areas



Appendix B

Area of Interest selection for NRCS Web Soil Survey near the proposed site.



Area of Interest Unified Soil Classification according to NRCS Web Soil Survey.

| Tables — Unified Soil Classification (Surface) — Summary By Map Unit | | | | | |
|--|---|--------|----------------|----------------|--|
| Summary by Map Unit — McKenzie County, North Dakota | | | | | |
| Map unit symbol | Map unit name | Rating | Acres in AOI | Percent of AOI | |
| 10 | Banks fine sandy loam, slightly wet, 0 to 2 percent slopes | CL-ML | 60.4 | 5.3% | |
| 16 | Ridgelawn silt loam, slightly wet, 0 to 2 percent slopes | CL | 136.8 | 12.0% | |
| 17 | Lohler silty clay, slightly wet, 0 to 2 percent slopes | CH | 271.0 | 23.7% | |
| 19 | Hoffmanville silty clay, slightly wet, 0 to 2 percent slopes | CH | 47.4 | 4.1% | |
| 20 | Scorio silty clay, slightly wet, 0 to 2 percent slopes | CH | 248.1 | 21.7% | |
| 95 | Havrelon silty clay, slightly wet, 0 to 2 percent slopes | CH | 127.6 | 11.2% | |
| 99 | Mckeen loam, 0 to 1 percent slopes | CL | 90.2 | 7.9% | |
| 171 | Lohler silty clay, saline, 0 to 1 percent slopes | CH | 32.9 | 2.9% | |
| 212 | Trembles fine sandy loam, slightly wet, 0 to 2 percent slopes | SC-SM | 9.3 | 0.8% | |
| 213 | Havrelon silt loam, slightly wet, 0 to 2 percent slopes | CL | 63.7 | 5.6% | |
| 299 | Minnewaukan-Banks-Riverwash complex, 0 to 2 percent slopes | SC-SM | 21.6 | 1.9% | |
| W | Water | | 34.3 | 3.0% | |
| Totals for Area of Interest | | | 1,143.3 | 100.0% | |

McKenzie County, North Dakota

17—Lohler silty clay, slightly wet, 0 to 2 percent slopes

Map Unit Setting

Elevation: 1,650 to 3,600 feet
Mean annual precipitation: 13 to 18 inches
Mean annual air temperature: 39 to 45 degrees F
Frost-free period: 120 to 135 days

Map Unit Composition

Lohler, sl wet, and similar soils: 93 percent
Minor components: 7 percent

Description of Lohler, Sl Wet

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water
(Ksat): Moderately low to moderately high (0.01 to 1.42 in/hr)
Depth to water table: About 42 to 60 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Available water capacity: High (about 9.1 inches)

Interpretive groups

Land capability (nonirrigated): 2e
Ecological site: Clayey (R054XY020ND)
Other vegetative classification: Overflow (G054XY500ND)

Typical profile

0 to 8 inches: Silty clay
8 to 60 inches: Silty clay

Minor Components

Havrelon, occasionally flooded

Percent of map unit: 4 percent
Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Loamy Terrace (R054XY041ND)
Other vegetative classification: Loam (G054XY100ND)

Lallie, occasionally flooded

Percent of map unit: 3 percent

Map Unit Description: Lohler silty clay, slightly wet, 0 to 2 percent slopes--
McKenzie County, North Dakota

Landform: Flood plains, oxbows on flood plains on river valleys
Down-slope shape: Linear
Across-slope shape: Concave
Ecological site: Wet Meadow (R054XY037ND)
Other vegetative classification: Wet (G054XY900ND)

Data Source Information

Soil Survey Area: McKenzie County, North Dakota
Survey Area Data: Version 15, Mar 31, 2008

McKenzie County, North Dakota

20—Scorio silty clay, slightly wet, 0 to 2 percent slopes

Map Unit Setting

Elevation: 1,650 to 3,600 feet
Mean annual precipitation: 13 to 18 inches
Mean annual air temperature: 39 to 45 degrees F
Frost-free period: 120 to 135 days

Map Unit Composition

Scorio, occasionally flooded, and similar soils: 76 percent
Minor components: 24 percent

Description of Scorio, Occasionally Flooded

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Clayey alluvium over loamy alluvium

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 20 to 40 inches to strongly contrasting textural stratification
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 1.42 in/hr)
Depth to water table: About 42 to 60 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Gypsum, maximum content: 5 percent
Available water capacity: Low (about 5.2 inches)

Interpretive groups

Land capability (nonirrigated): 2e
Ecological site: Loamy Terrace (R054XY041ND)
Other vegetative classification: Overflow (G054XY500ND)

Typical profile

0 to 8 inches: Silty clay
8 to 32 inches: Silty clay
32 to 60 inches: Fine sandy loam

Minor Components

Scorio, occasionally flooded

Percent of map unit: 10 percent
Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Loamy Terrace (R054XY041ND)

Other vegetative classification: Overflow (G054XY500ND)

Lohler, sl wet

Percent of map unit: 6 percent

Landform: Flood plains

Down-slope shape: Linear

Across-slope shape: Linear

Ecological site: Clayey (R054XY020ND)

Other vegetative classification: Overflow (G054XY500ND)

Scorio, saline,occasionally flooded

Percent of map unit: 5 percent

Landform: Flood plains on river valleys

Down-slope shape: Linear

Across-slope shape: Linear

Ecological site: Saline Lowland (R054XY024ND)

Other vegetative classification: Saline (G054XY895ND)

Havreton, occasionally flooded

Percent of map unit: 3 percent

Landform: Flood plains

Down-slope shape: Linear

Across-slope shape: Linear

Ecological site: Loamy Terrace (R054XY041ND)

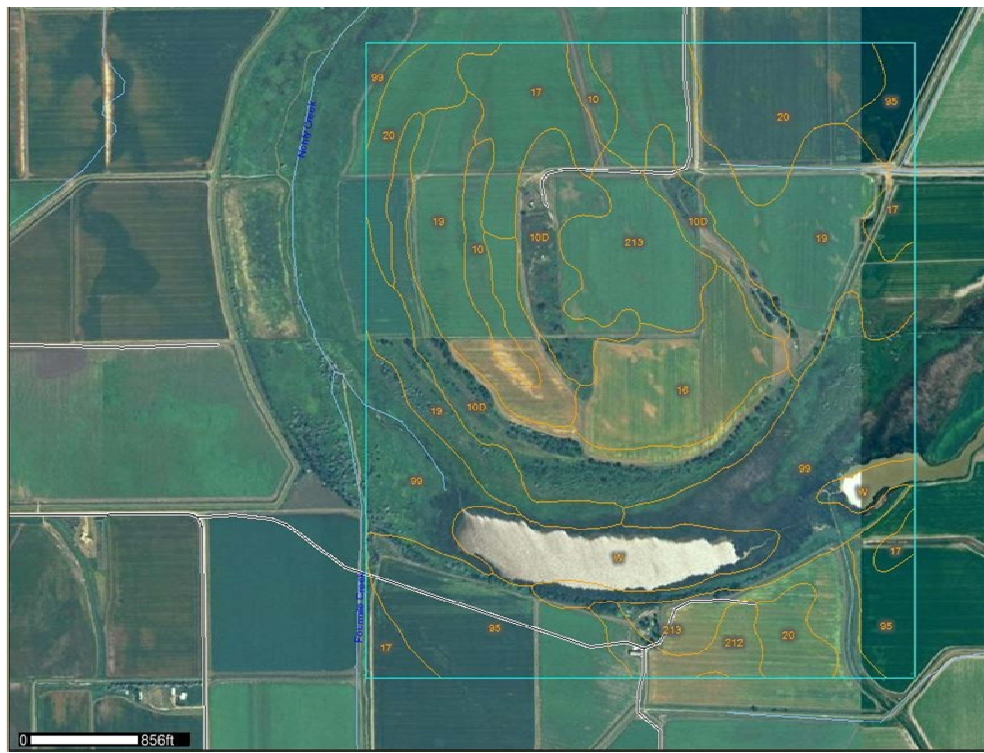
Other vegetative classification: Loam (G054XY100ND)

Data Source Information

Soil Survey Area: McKenzie County, North Dakota

Survey Area Data: Version 15, Mar 31, 2008

Area of Interest selection for NRCS Web Soil Survey for the Toe Drain Material.



Area of Interest Unified Soil Classification according to NRCS Web Soil Survey.

| McKenzie County, North Dakota (ND053) | | | |
|---------------------------------------|---|--------------|----------------|
| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
| 10 | Banks fine sandy loam, slightly wet, 0 to 2 percent slopes | 11.5 | 2.3% |
| 10D | Seroco-Lohler complex, 0 to 15 percent slopes | 65.3 | 13.2% |
| 16 | Ridgelawn silt loam, slightly wet, 0 to 2 percent slopes | 30.5 | 6.2% |
| 17 | Lohler silty clay, slightly wet, 0 to 2 percent slopes | 32.1 | 6.5% |
| 19 | Hoffmanville silty clay, slightly wet, 0 to 2 percent slopes | 101.2 | 20.5% |
| 20 | Scorio silty clay, slightly wet, 0 to 2 percent slopes | 48.5 | 9.8% |
| 95 | Havreton silty clay, slightly wet, 0 to 2 percent slopes | 49.5 | 10.1% |
| 99 | McKeen loam, 0 to 1 percent slopes | 75.2 | 15.3% |
| 212 | Trembles fine sandy loam, slightly wet, 0 to 2 percent slopes | 10.0 | 2.0% |
| 213 | Havreton silt loam, slightly wet, 0 to 2 percent slopes | 39.9 | 8.1% |

Map Unit Description

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

McKenzie County, North Dakota

10D—Seroco-Lohler complex, 0 to 15 percent slopes

Map Unit Setting

Elevation: 1,650 to 3,600 feet
Mean annual precipitation: 13 to 18 inches
Mean annual air temperature: 39 to 45 degrees F
Frost-free period: 120 to 135 days

Map Unit Composition

Seroco and similar soils: 90 percent
Lohler and similar soils: 10 percent

Description of Seroco

Setting

Landform: Dunes, knobs, ridges

Landform position (two-dimensional): Summit, shoulder

Down-slope shape: Convex

Across-slope shape: Convex

Parent material: Sandy alluvium derived from sedimentary rock and/
or eolian sands

Properties and qualities

Slope: 0 to 15 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Excessively drained

Capacity of the most limiting layer to transmit water

(Ksat): Moderately high to very high (1.42 to 99.90 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Calcium carbonate, maximum content: 5 percent

Available water capacity: Low (about 4.9 inches)

Interpretive groups

Land capability (nonirrigated): 6e

Ecological site: Thin Sands (R054XY034ND)

Other vegetative classification: Not suited (G054XY000ND)

Typical profile

0 to 3 inches: Loamy fine sand

3 to 60 inches: Fine sand

Description of Lohler

Setting

Landform: Flood plains

Down-slope shape: Linear

Across-slope shape: Linear

Properties and qualities

Slope: 0 to 2 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Moderately well drained

Capacity of the most limiting layer to transmit water

(Ksat): Moderately low to moderately high (0.01 to 1.42 in/hr)

Depth to water table: About 42 to 60 inches

Frequency of flooding: Occasional

Frequency of ponding: None

Calcium carbonate, maximum content: 20 percent

Available water capacity: High (about 9.7 inches)

Interpretive groups

Land capability (nonirrigated): 2e

Ecological site: Clayey (R054XY020ND)

Other vegetative classification: Overflow (G054XY500ND)

Typical profile

0 to 8 inches: Silty clay

8 to 60 inches: Silty clay

Data Source Information

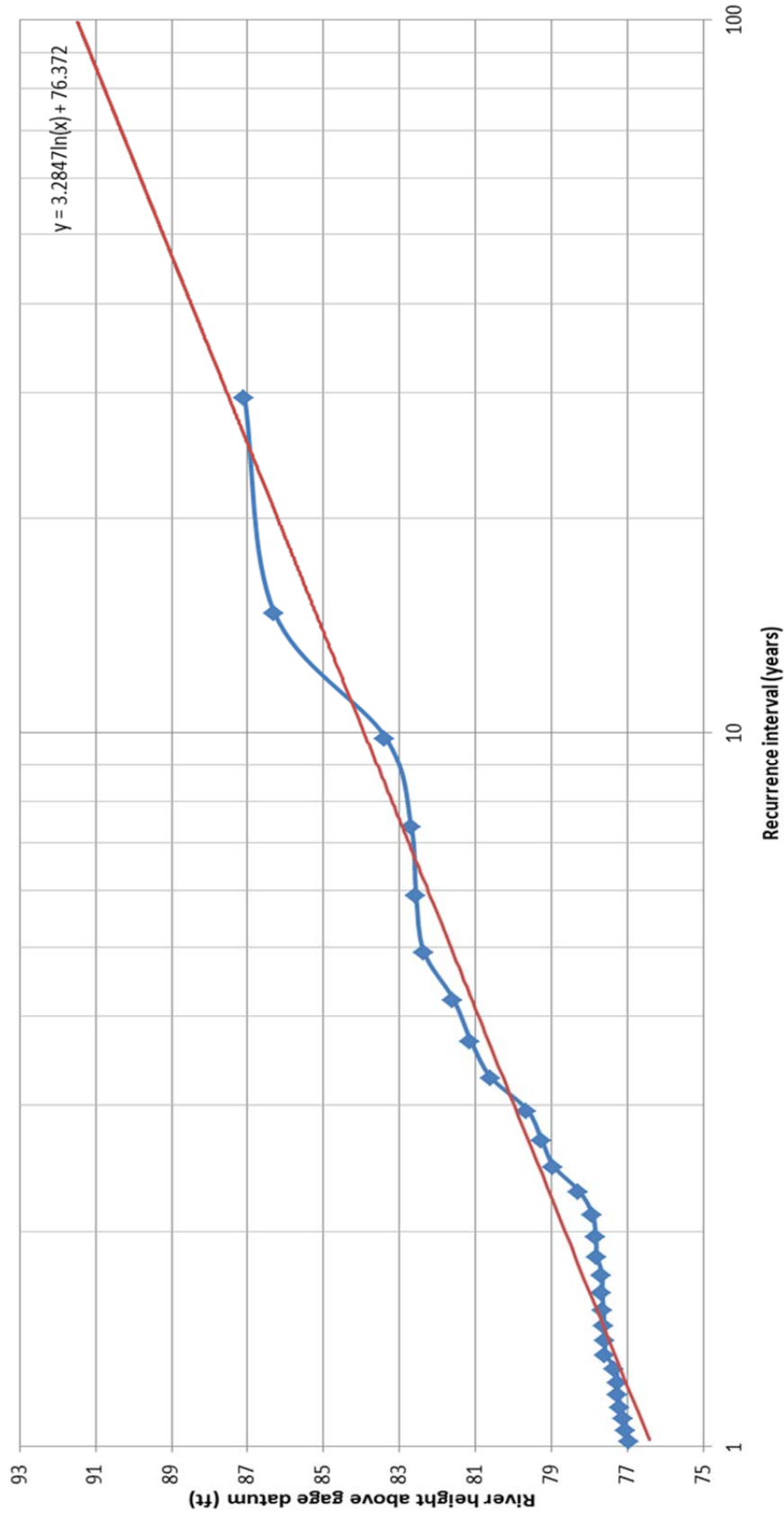
Soil Survey Area: McKenzie County, North Dakota

Survey Area Data: Version 15, Mar 31, 2008

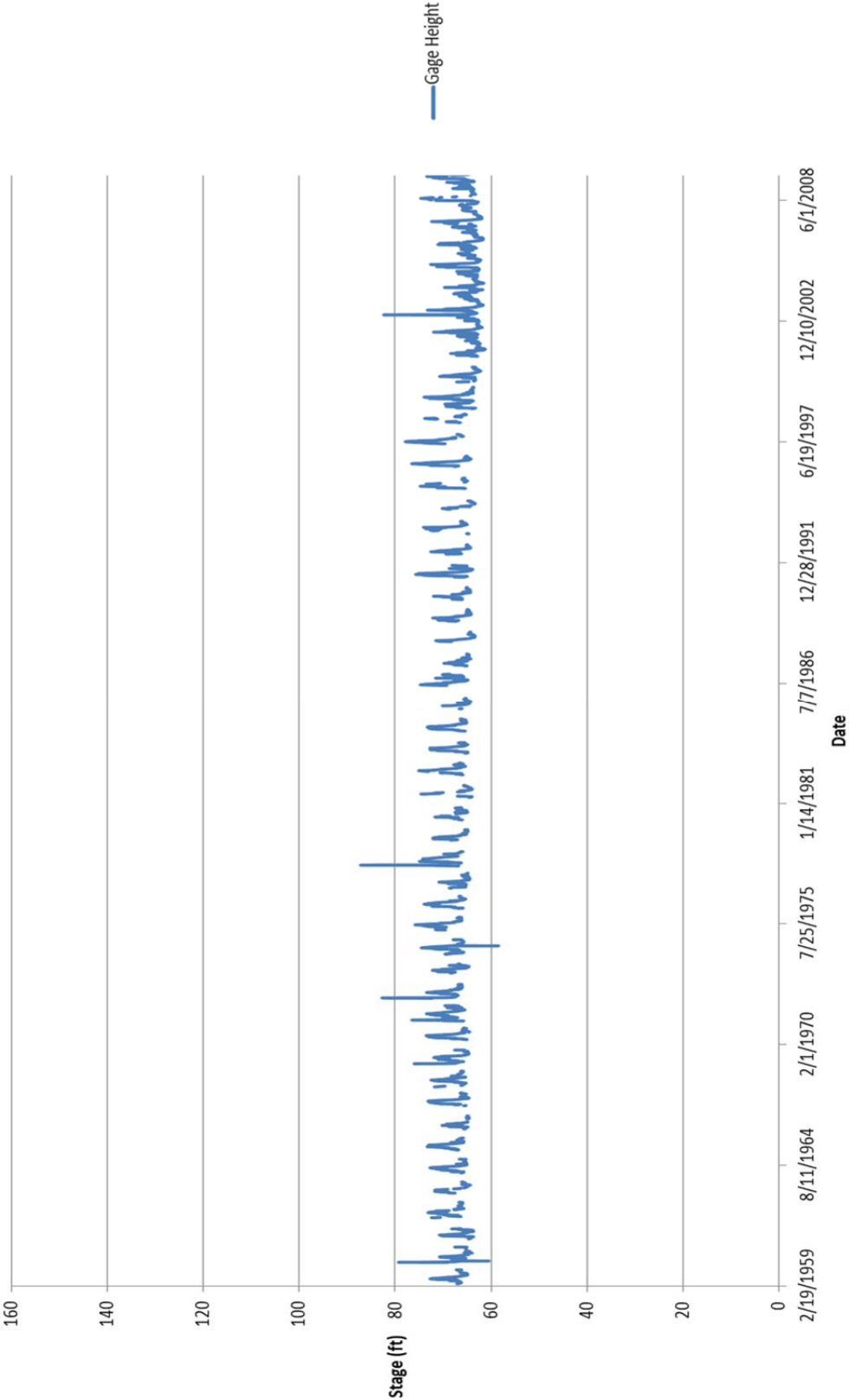
Appendix C

| | | |
|--|------------|-----------|
| Gage height readings | | |
| Date | Cartwright | Williston |
| 11 | 64.11 | 14.09 |
| 12 | 64.12 | 14.08 |
| 13 | 64.12 | 14.09 |
| 14 | 64.12 | 14.09 |
| 15 | 64.12 | 14.08 |
| | | |
| Average | 64.118 | 14.086 |
| | | |
| Datum | 1800 | 1830.2 |
| Elevation | 1864.118 | 1844.286 |
| | | |
| Elevation Difference (ft) | | 19.832 |
| Total Distance (ft) | | 175560 |
| River slope (ft/ft) | | 0.000113 |
| | | |
| Distance from Cartwright station to site (ft) | | 31680 |
| River elevation at site | | 1860.539 |
| | | |
| Calc. Datum of site with respect to Cartwright | | 1796.421 |

Flood Frequency Diagram for the Yellowstone River at Cartwright, ND



Stage Height at Cartwright USGS Station (06329610)



— Gage Height

Appendix D

Bore Hole Soil Log

| PROJECT: Senior Design | | | | | | |
|---------------------------------|-------------------|---|-----------------------|--------------------|-------------------|-----------------|
| DATE: 3/18/2010 | | | | | | |
| LOCATION: B-1 | | | | | | |
| METHOD: Hand Auger | | | | | | |
| DRILLER: Matthew Carns | | | | | | |
| Elevation feet 1892 MSL | Depth feet 0.0 | Description of Materials | Sample # and Depth | Water Content % | Shear Strength | Compressibility |
| ----- ----- ----- 1891 | 1.0 | Fine-grained brown silt, some organic material and clay | S-1 | 9.93 | 3.4 | 1.47 |
| ----- ----- ----- 1890 | 2.0 | Medium-grained brown silt | S-2 | | | |
| ----- ----- ----- 1889 | 3.0 | Clayey fine-grained brown silt, some organic material (roots) | ST-1, 2.50 ft S-3 | 7.74 | | |
| ----- ----- ----- 1888 | 4.0 | Very fine-grained silt, some organic material (roots) | ST-2, 3.25 ft S-4 | | 2.85 | 0.73 |
| ----- ----- ----- 1887 | 5.0 | Medium-grained silt, little to no clay | S-5 | 4.82 | 1.43 | 0.6 |
| ----- ----- ----- 1886 | 6.0 | Coarse to medium- grained silt, well sorted | ST-3, 5.25 ft S-6 | | | |

Bore Hole and Shelby Tube Info

March 18, 2010

Matthew Carns

Location Information

N 47.94629 W 103.96830

1892 ft above sea level

Site is not used for crops currently

Some standing water existed around the site, upper soil layers were moist

put in oven 10:30 am 3-26-10

Loose Soil Samples

| Sample # | Depth (ft) | cup # | cup mass (g) | moist mass (g) | dry mass (g) | moisture content % |
|----------|------------|-------|-----------------|-------------------|-----------------|-----------------------|
| 1 | 1.0 | a003 | 21.6 | 41.3 | 37.2 | 9.93 |
| 2 | 2.0 | | | | | |
| 3 | 3.0 | a004 | 21.4 | 33.6 | 31 | 7.74 |
| 4 | 4.0 | | | | | |
| 5 | 5.0 | a005 | 21.4 | 35.3 | 33.6 | 4.82 |
| 6 | 6.0 | | | | | |

Shelby Tube Samples

Sample 1

| | | | |
|-----------------|------|------|------|
| Depth (ft) | 2.50 | | |
| Shear | 3.75 | 3.30 | 3.15 |
| Avg. Shear | 3.40 | | |
| Compressibility | 1.50 | 1.40 | 1.50 |
| Avg. Comp. | 1.47 | | |

Sample 2

| | | | |
|-----------------|------|------|------|
| Depth (ft) | 3.25 | | |
| Shear | 3.25 | 2.50 | 2.80 |
| Avg. Shear | 2.85 | | |
| Compressibility | 0.70 | 0.75 | 0.75 |
| Avg. Comp. | 0.73 | | |

Sample 3

| | | | |
|-----------------|------|------|------|
| Depth (ft) | 5.25 | | |
| Shear | 1.50 | 1.40 | 1.40 |
| Avg. Shear | 1.43 | | |
| Compressibility | 0.50 | 0.60 | 0.70 |
| Avg. Comp. | 0.60 | | |

Seive and Hydrometer Analysis

Sample # 1

Seive Analysis

mass bowl (g) 130.5
mass soil (g) 75.0

| Seive # | Mass Retained (g) | Cumulative Mass Retained | % Passing |
|---------|-------------------|--------------------------|-----------|
| 16 | 0.08 | 0.08 | 99.89 |
| 30 | 0.22 | 0.30 | 99.60 |
| 50 | 1.05 | 1.35 | 98.20 |
| 100 | 2.94 | 4.29 | 94.28 |
| 200 | 5.83 | 10.12 | 86.51 |

mass past #200 (g) 63
mass above #200 (g) 10.1
% retained on #200 13.5
% finer than #200 86.5

Seive and Hydrometer Analysis

Sample # 2

Seive Analysis

mass bowl (g) 106.5
mass soil (g) 75.0

| Seive # | Mass Retained (g) | Cumulative Mass | |
|---------|-------------------|-----------------|-----------|
| | | Retained (g) | % Passing |
| 16 | 0.04 | 0.04 | 99.95 |
| 30 | 0.17 | 0.21 | 99.72 |
| 50 | 0.83 | 1.04 | 98.61 |
| 100 | 1.02 | 2.06 | 97.25 |
| 200 | 1.62 | 3.68 | 95.09 |

mass past #200 (g) 69.77
mass above #200 (g) 3.6
% retained on #200 4.8
% finer than #200 95.2

Seive and Hydrometer Analysis

Sample # 3

Seive Analysis

mass bowl (g) 128.5
mass soil (g) 75.0

| Seive # | Mass Retained (g) | Cumulative Mass | |
|---------|-------------------|-----------------|-----------|
| | | Retained (g) | % Passing |
| 16 | 0.21 | 0.21 | 99.72 |
| 30 | 0.87 | 1.08 | 98.56 |
| 50 | 1.09 | 2.17 | 97.11 |
| 100 | 0.74 | 2.91 | 96.12 |
| 200 | 2.96 | 5.87 | 92.17 |

mass past #200 (g) 67.4
mass above #200 (g) 5.9
% retained on #200 7.8
% finer than #200 92.2

Seive and Hydrometer Analysis

Sample # 4

Seive Analysis

mass bowl (g) 128.2
mass soil (g) 75.0

| Seive # | Mass Retained (g) | Cumulative Mass Retained | |
|---------|-------------------|--------------------------|-----------|
| | | (g) | % Passing |
| 16 | 0.03 | 0.03 | 99.96 |
| 30 | 0.10 | 0.13 | 99.83 |
| 50 | 0.46 | 0.59 | 99.21 |
| 100 | 0.71 | 1.30 | 98.27 |
| 200 | 1.42 | 2.72 | 96.37 |

mass past #200 (g) 71.86
mass above #200 (g) 2.72
% retained on #200 4.19
% finer than #200 95.81

Seive and Hydrometer Analysis

Sample # 5

Seive Analysis

| | |
|---------------|-------|
| mass bowl (g) | 108.7 |
| mass soil (g) | 75.0 |

| Seive # | Mass Retained (g) | Cumulative Mass Retained (g) | % Passing |
|---------|-------------------|---------------------------------|-----------|
| 16 | 0.02 | 0.02 | 99.97 |
| 30 | 0.03 | 0.05 | 99.93 |
| 50 | 0.26 | 0.31 | 99.59 |
| 100 | 0.97 | 1.28 | 98.29 |
| 200 | 1.24 | 2.52 | 96.64 |

| | |
|---------------------|-------|
| mass past #200 (g) | 72.10 |
| mass above #200 (g) | 2.52 |
| % retained on #200 | 3.87 |
| % finer than #200 | 96.13 |

Seive and Hydrometer Analysis

Sample # 6

Seive Analysis

mass bowl (g) 118.7
mass soil (g) 75.0

| Seive # | Mass Retained (g) | Cumulative Mass Retained (g) | % Passing |
|---------|-------------------|---------------------------------|-----------|
| 16 | 0.03 | 0.03 | 99.96 |
| 30 | 0.03 | 0.06 | 99.92 |
| 50 | 0.22 | 0.28 | 99.63 |
| 100 | 0.97 | 1.25 | 98.33 |
| 200 | 3.10 | 4.35 | 94.20 |

mass past #200 (g) 69.86
mass above #200 (g) 4.35
% retained on #200 5.80
% finer than #200 94.20

Grain Size Analysis - Hydrometer Method

ASTM - D - 422 __A__

Project:
Location:
Soil Description:
Test By:

Job Number:
Sample ID: 1
Date of Collection:
Date of Testing:

Hydrometer Analysis

Hydrometer Type: **152H** Zero Correction: **6.0** Meniscus: **1.5**
Dispersing Agent: **Calgon** Amount Used: **4% @ 125 ml**
G_s of Solids: **2.65** CF a = **1.00** w (air-dry) = **1**
Soil Mass: **63.00000** grams % Finer = **86.5%** Control Sieve no: **200**
☒ Dry ☐ Wet

| Date and Time of Reading | Elapsed Time, min | Temp., °C | Actual Hyd. reading, R _s | Corrected Hyd. reading, R _c | Actual % Finer | Adjusted % Finer | D, mm | D, µm |
|--------------------------|-------------------|-----------|-------------------------------------|--|----------------|------------------|---------|-------|
| 10/13/2010 13:28 | 0 | | | | | 86.5% | | 74.00 |
| | 2 | 21.5 ° | 48.0 | 42.20 | 67.0% | 57.9% | 0.02717 | 27.17 |
| | 6 | 21.5 ° | 42.0 | 36.20 | 57.5% | 49.7% | 0.01663 | 16.63 |
| | 10 | 21.5 ° | 39.0 | 33.20 | 52.7% | 45.6% | 0.01323 | 13.23 |
| | 15 | 21.5 ° | 36.5 | 30.70 | 48.7% | 42.2% | 0.01108 | 11.08 |
| | 30.5 | 22.0 ° | 33.0 | 27.40 | 43.5% | 37.6% | 0.00780 | 7.80 |
| | 60 | 22.0 ° | 28.5 | 22.90 | 36.3% | 31.4% | 0.00580 | 5.80 |
| 10/13/2010 15:50 | 141 | 22.5 ° | 23.5 | 17.90 | 28.4% | 24.6% | 0.00391 | 3.91 |
| 10/13/2010 16:51 | 202 | 22.5 ° | 21.5 | 15.90 | 25.2% | 21.8% | 0.00331 | 3.31 |
| 10/13/2010 18:46 | 317 | 22.5 ° | 18.5 | 12.90 | 20.5% | 17.7% | 0.00269 | 2.69 |
| 10/13/2010 20:55 | 446 | 22.5 ° | 16.0 | 10.40 | 16.5% | 14.3% | 0.00230 | 2.30 |
| 10/14/2010 10:30 | 1261 | 22.5 ° | 12.5 | 6.90 | 11.0% | 9.5% | 0.00140 | 1.40 |
| 10/14/2010 14:37 | 1508 | 22.5 ° | 11.5 | 5.90 | 9.4% | 8.1% | 0.00129 | 1.29 |

Comments:

Grain Size Analysis - Hydrometer Method

ASTM - D - 422 __A__

Project:
Location:
Soil Description:
Test By:

Job Number:
Sample ID: 2
Date of Collection:
Date of Testing:

Hydrometer Analysis

Hydrometer Type: **152H** Zero Correction: **7.0** Meniscus: **1.5**
Dispersing Agent: **Calgon** Amount Used: **4% @ 125 ml**
G_s of Solids: **2.65** CF a = 1.00 w (air-dry) = 1
Soil Mass: 69.77000 grams % Finer = **95.1%** Control Sieve no: **200**
☒ Dry ☐ Wet

| Date and Time of Reading | Elapsed Time, min | Temp., °C | Actual Hyd. reading, R _s | Corrected Hyd. reading, R _c | Actual % Finer | Adjusted % Finer | D, mm | D, µm |
|--------------------------|-------------------|-----------|-------------------------------------|--|----------------|------------------|---------|-------|
| 10/5/2010 15:42 | 0 | | | | | 95.1% | | 74.00 |
| | 2 | 22.0 ° | 62.0 | 55.40 | 79.4% | 75.5% | 0.02398 | 23.98 |
| | 6 | 22.0 ° | 49.5 | 42.90 | 61.5% | 58.5% | 0.01526 | 15.26 |
| | 10 | 22.0 ° | 38.5 | 31.90 | 45.7% | 43.5% | 0.01310 | 13.10 |
| | 15 | 22.0 ° | 26.0 | 19.40 | 27.8% | 26.4% | 0.01175 | 11.75 |
| | 30.5 | 22.0 ° | 21.0 | 14.40 | 20.6% | 19.6% | 0.00851 | 8.51 |
| | 60 | 22.0 ° | 17.5 | 10.90 | 15.6% | 14.9% | 0.00624 | 6.24 |
| 10/5/2010 17:54 | 131 | 22.5 ° | 14.5 | 7.90 | 11.3% | 10.8% | 0.00430 | 4.30 |
| 10/5/2010 20:24 | 281 | 22.5 ° | 12.0 | 5.40 | 7.7% | 7.4% | 0.00297 | 2.97 |
| 10/6/2010 9:46 | 1083 | 22.0 ° | 9.5 | 2.90 | 4.2% | 4.0% | 0.00154 | 1.54 |
| 10/6/2010 15:55 | 1452 | 22.0 ° | 8.5 | 1.90 | 2.7% | 2.6% | 0.00134 | 1.34 |
| | | | | | | | | |
| | | | | | | | | |

Comments:

Grain Size Analysis - Hydrometer Method

ASTM - D - 422 ___ A ___

Project:
Location:
Soil Description:
Test By:

Job Number:
Sample ID: 3
Date of Collection:
Date of Testing:

Hydrometer Analysis

Hydrometer Type: **152H** Zero Correction: **7.0** Meniscus: **1.5**
Dispersing Agent: **Calgon** Amount Used: **4% @ 125 ml**
G_s of Solids: **2.65** CF a = **1.00** w (air-dry) = **1**
Soil Mass: **67.40000** grams % Finer = **92.2%** Control Sieve no: **200**
☒ Dry ☐ Wet

| Date and Time of Reading | Elapsed Time, min | Temp., °C | Actual Hyd. reading, R _s | Corrected Hyd. reading, R _c | Actual % Finer | Adjusted % Finer | D, mm | D, µm |
|--------------------------|-------------------|-----------|-------------------------------------|--|----------------|------------------|---------|-------|
| 10/17/2010 11:17 | 0 | | | | | 92.2% | | 74.00 |
| | 2 | 21.0 ° | 46.5 | 39.70 | 58.9% | 54.3% | 0.02767 | 27.67 |
| | 6 | 21.0 ° | 41.0 | 34.20 | 50.7% | 46.8% | 0.01672 | 16.72 |
| | 10 | 21.0 ° | 38.0 | 31.20 | 46.3% | 42.7% | 0.01330 | 13.30 |
| | 15 | 21.0 ° | 36.5 | 29.70 | 44.1% | 40.6% | 0.01108 | 11.08 |
| | 30 | 21.0 ° | 33.0 | 26.20 | 38.9% | 35.8% | 0.00799 | 7.99 |
| | 60 | 21.0 ° | 30.0 | 23.20 | 34.4% | 31.7% | 0.00581 | 5.81 |
| 10/17/2010 13:15 | 117 | 21.5 ° | 27.5 | 20.70 | 30.7% | 28.3% | 0.00423 | 4.23 |
| 10/17/2010 15:55 | 277 | 22.5 ° | 23.5 | 16.90 | 25.1% | 23.1% | 0.00279 | 2.79 |
| 10/17/2010 23:15 | 717 | 22.5 ° | 20.5 | 13.90 | 20.6% | 19.0% | 0.00177 | 1.77 |
| 10/18/2010 7:30 | 1212 | 22.5 ° | 17.5 | 10.90 | 16.2% | 14.9% | 0.00139 | 1.39 |
| 10/18/2010 15:54 | 1716 | 22.5 ° | 14.5 | 7.90 | 11.7% | 10.8% | 0.00119 | 1.19 |
| 10/18/2010 19:27 | 1929 | 22.5 ° | 13.5 | 6.90 | 10.2% | 9.4% | 0.00112 | 1.12 |

Comments:

Grain Size Analysis - Hydrometer Method

ASTM - D - 422 ___ A ___

Project:
Location:
Soil Description:
Test By:

Job Number:
Sample ID: 4
Date of Collection:
Date of Testing:

Hydrometer Analysis

Hydrometer Type: 152H Zero Correction: 7.0 Meniscus: 1.5
Dispersing Agent: Calgon Amount Used: 4% @ 125 ml
G_s of Solids: 2.65 CF a = 1.00 w (air-dry) = 1
Soil Mass: 71.86000 grams % Finer = 96.4% Control Sieve no: 200
☒ Dry ☐ Wet

| Date and Time of Reading | Elapsed Time, min | Temp., °C | Actual Hyd. reading, R _s | Corrected Hyd. reading, R _c | Actual % Finer | Adjusted % Finer | D, mm | D, µm |
|--------------------------|-------------------|-----------|-------------------------------------|--|----------------|------------------|---------|-------|
| 10/20/2010 17:56 | 0 | | | | | 96.4% | | 74.00 |
| | 15 | 23.5 ° | 63.0 | 56.70 | 78.9% | 76.0% | 0.00869 | 8.69 |
| | 30 | 23.5 ° | 60.5 | 54.20 | 75.4% | 72.7% | 0.00614 | 6.14 |
| | 45 | 23.5 ° | 58.5 | 52.20 | 72.6% | 70.0% | 0.00502 | 5.02 |
| | 60 | 23.5 ° | 57.0 | 50.70 | 70.6% | 68.0% | 0.00438 | 4.38 |
| | 159 | 23.5 ° | 47.0 | 40.70 | 56.6% | 54.6% | 0.00302 | 3.02 |
| | 259 | 23.5 ° | 38.5 | 32.20 | 44.8% | 43.2% | 0.00255 | 2.55 |
| 10/21/2010 10:56 | 1020 | 23.5 ° | 10.5 | 4.20 | 5.8% | 5.6% | 0.00156 | 1.56 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Comments:

Grain Size Analysis - Hydrometer Method

ASTM - D - 422 __ A __

Project:
Location:
Soil Description:
Test By:

Job Number:
Sample ID: 5
Date of Collection:
Date of Testing:

Hydrometer Analysis

Hydrometer Type: 152H Zero Correction: 7.0 Meniscus: 1.5
Dispersing Agent: Calgon Amount Used: 4% @ 125 ml
G_s of Solids: 2.65 CF a = 1.00 w (air-dry) = 1
Soil Mass: 72.10000 grams % Finer = 96.6% Control Sieve no: 200
☒ Dry ☐ Wet

| Date and Time of Reading | Elapsed Time, min | Temp., °C | Actual Hyd. reading, R _s | Corrected Hyd. reading, R _c | Actual % Finer | Adjusted % Finer | D, mm | D, µm |
|--------------------------|-------------------|-----------|-------------------------------------|--|----------------|------------------|---------|-------|
| 10/19/2010 16:31 | 0 | | | | | 96.6% | | 74.00 |
| | 1 | 23.0 ° | 58.5 | 52.20 | 72.4% | 70.0% | 0.03365 | 33.65 |
| | 2 | 23.0 ° | 50.5 | 44.20 | 61.3% | 59.2% | 0.02607 | 26.07 |
| | 3 | 23.0 ° | 45.5 | 39.20 | 54.4% | 52.5% | 0.02235 | 22.35 |
| | 6 | 23.0 ° | 37.0 | 30.70 | 42.6% | 41.1% | 0.01696 | 16.96 |
| | 10 | 23.0 ° | 26.0 | 19.70 | 27.3% | 26.4% | 0.01428 | 14.28 |
| | 15 | 23.0 ° | 20.5 | 14.20 | 19.7% | 19.0% | 0.01215 | 12.15 |
| 10/19/2010 16:51 | 20 | 23.0 ° | 16.0 | 9.70 | 13.5% | 13.0% | 0.01076 | 10.76 |
| 10/19/2010 16:56 | 25 | 23.0 ° | 15.0 | 8.70 | 12.1% | 11.7% | 0.00970 | 9.70 |
| 10/19/2010 17:05 | 34 | 23.0 ° | 13.5 | 7.20 | 10.0% | 9.7% | 0.00841 | 8.41 |
| 10/19/2010 17:15 | 44 | 23.0 ° | 13.0 | 6.70 | 9.3% | 9.0% | 0.00739 | 7.39 |
| 10/19/2010 19:45 | 194 | 23.0 ° | 10.0 | 3.70 | 5.1% | 5.0% | 0.00358 | 3.58 |
| | | | | | | | | |

Comments:

Grain Size Analysis - Hydrometer Method

ASTM - D - 422 ___A___

Project:
Location:
Soil Description:
Test By:

Job Number:
Sample ID: 6
Date of Collection:
Date of Testing:

Hydrometer Analysis

Hydrometer Type: **152H** Zero Correction: **7.0** Meniscus: **1.5**
Dispersing Agent: **Calgon** Amount Used: **4% @ 125 ml**
G_s of Solids: **2.65** CF a = **1.00** w (air-dry) = **1**
Soil Mass: **69.86000** grams % Finer = **94.2%** Control Sieve no: **200**
☒ Dry ☐ Wet

| Date and Time of Reading | Elapsed Time, min | Temp., °C | Actual Hyd. reading, R _a | Corrected Hyd. reading, R _c | Actual % Finer | Adjusted % Finer | D, mm | D, µm |
|--------------------------|-------------------|-----------|-------------------------------------|--|----------------|------------------|---------|-------|
| 10/19/2010 16:09 | 0 | | | | | 94.2% | | 74.00 |
| | 2 | 23.0 ° | 46.5 | 40.20 | 57.5% | 54.2% | 0.02705 | 27.05 |
| | 4 | 23.0 ° | 28.0 | 21.70 | 31.1% | 29.3% | 0.02228 | 22.28 |
| | 6 | 23.0 ° | 13.5 | 7.20 | 10.3% | 9.7% | 0.02002 | 20.02 |
| | 8 | 23.0 ° | 10.5 | 4.20 | 6.0% | 5.7% | 0.01765 | 17.65 |
| | 10 | 23.0 ° | 9.5 | 3.20 | 4.6% | 4.3% | 0.01589 | 15.89 |
| | 15 | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
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| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Comments:

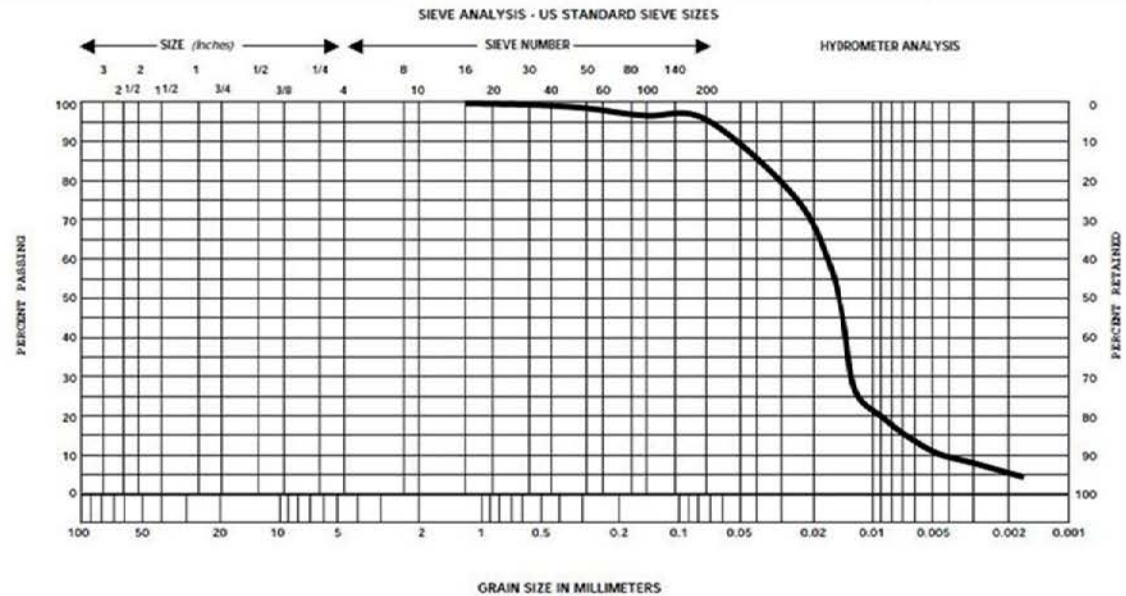
GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADATION CHART

1. PROJECT

Senior Design

2. DATE

10/14/2010



| EXCAVATION NUMBER | SAMPLE NUMBER | LL | PL | PI | Cu (D ₆₀ /D ₁₀) | Cc (D ₆₀) ² / (D ₁₀ × D ₃₀) | SOIL DESCRIPTION/REMARKS | CLASSIFICATION (USCS) |
|---------------------------|---------------|----|----|---------------------------|---|--|---------------------------|-----------------------|
| B-1 | S-2 | | | | | | | |
| 3. TECHNICIAN (Signature) | | | | 4. PLOTTED BY (Signature) | | | 5. CHECKED BY (Signature) | |

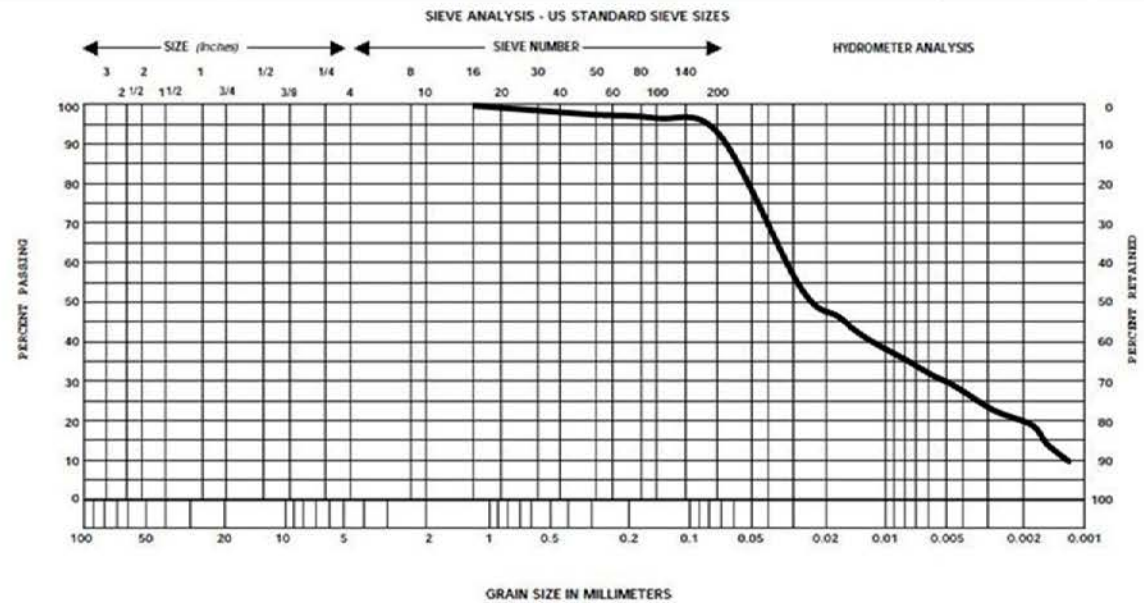
GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADATION CHART

1. PROJECT

Senior Design

2. DATE

10/18/2010



| EXCAVATION NUMBER | SAMPLE NUMBER | LL | PL | PI | Cu (D_{60}/D_{10}) | Cc ($D_{30}^2 / (D_{10} \times D_{60})$) | SOIL DESCRIPTION/REMARKS | CLASSIFICATION (USCS) |
|---------------------------|---------------|----|----|---------------------------|---------------------------|---|---------------------------|-----------------------|
| B-1 | S-3 | | | | | | | |
| 3. TECHNICIAN (Signature) | | | | 4. PLOTTED BY (Signature) | | | 5. CHECKED BY (Signature) | |

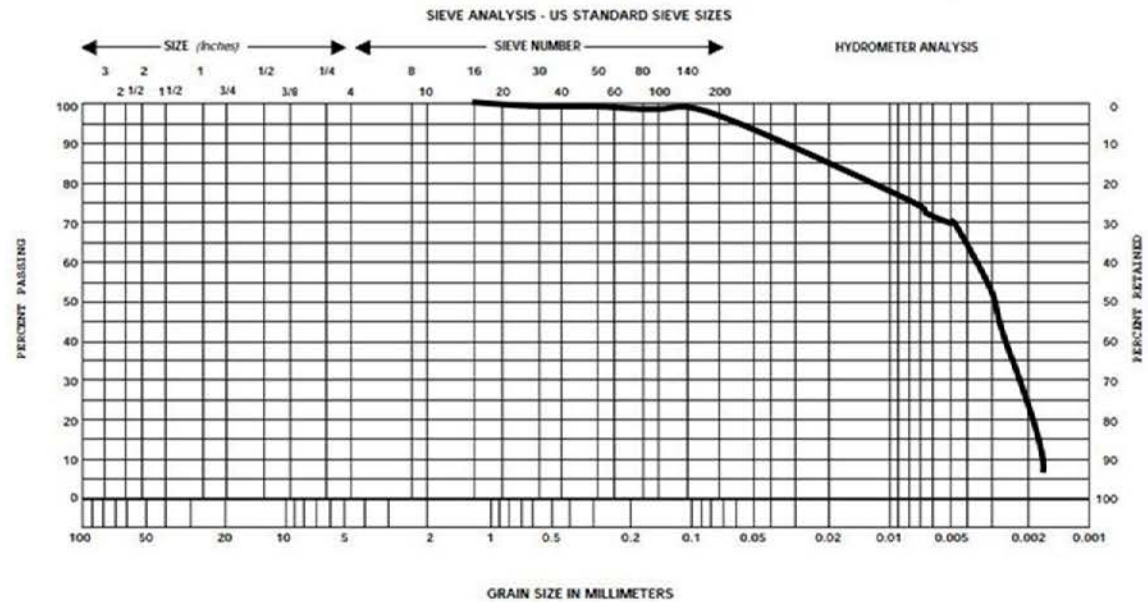
GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADATION CHART

1. PROJECT

Senior Design

2. DATE

10/21/2010



| EXCAVATION NUMBER | SAMPLE NUMBER | L.I. | PL | PI | C_u (D_{60}/D_{10}) | C_c ($(D_{60})^2 / (D_{10} \times D_{30})$) | SOIL DESCRIPTION/REMARKS | CLASSIFICATION (USCS) |
|---------------------------|---------------|------|----|---------------------------|------------------------------|--|---------------------------|-----------------------|
| B-1 | S-4 | | | | | | | |
| 3. TECHNICIAN (Signature) | | | | 4. PLOTTED BY (Signature) | | | 5. CHECKED BY (Signature) | |

Appendix E

Hydraulic Conductivity Calculations

| Sample | D_{10} | D_{50} | D_{90} | I_0 | U | n | e |
|--------|----------|----------|----------|---------|--------|-------|-------|
| 1 | 0.0015 | 0.017 | 0.03 | 0.00105 | 20.000 | 0.261 | 0.353 |
| 2 | 0.0041 | 0.0135 | 0.016 | 0.0023 | 3.902 | 0.378 | 0.608 |
| 3 | 0.00115 | 0.0225 | 0.031 | 0.0005 | 26.957 | 0.257 | 0.345 |
| 4 | 0.0017 | 0.029 | 0.034 | 0.00135 | 2.000 | 0.431 | 0.756 |
| 5 | 0.009 | 0.02 | 0.0261 | 0.0073 | 2.900 | 0.404 | 0.677 |
| 6 | 0.0205 | 0.0255 | 0.0308 | 0.019 | 1.502 | 0.448 | 0.811 |

Alyamani & Sen Method

$$K = 1300 * [I_0 + .025(d_{30} - d_{10})]^2$$

| Sample | m/day | cm/sec | ln(K) |
|-------------|------------|------------|-----------|
| 1 | 2.6863E-03 | 3.1092E-06 | -12.68115 |
| 2 | 8.3541E-03 | 9.6691E-06 | -11.54658 |
| 3 | 1.3892E-03 | 1.6079E-06 | -13.34058 |
| 4 | 5.3704E-03 | 6.2157E-06 | -11.98843 |
| 5 | 7.4595E-02 | 8.6337E-05 | -9.357257 |
| 6 | 4.7550E-01 | 5.5034E-04 | -7.504971 |
| sum ln(K) = | | | -66.41897 |

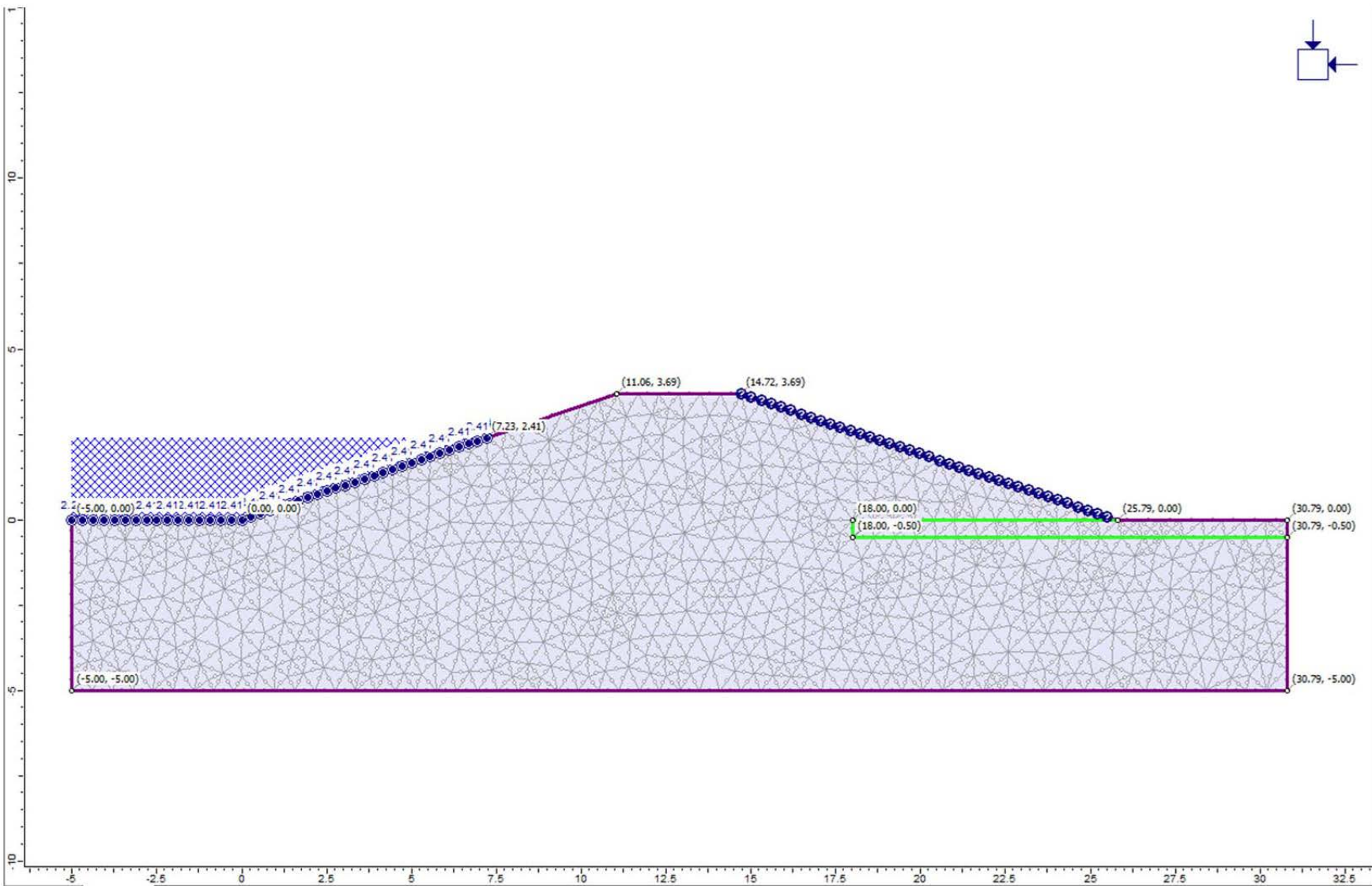
Geometric Avg. K (cm/sec)=
1.55752E-05

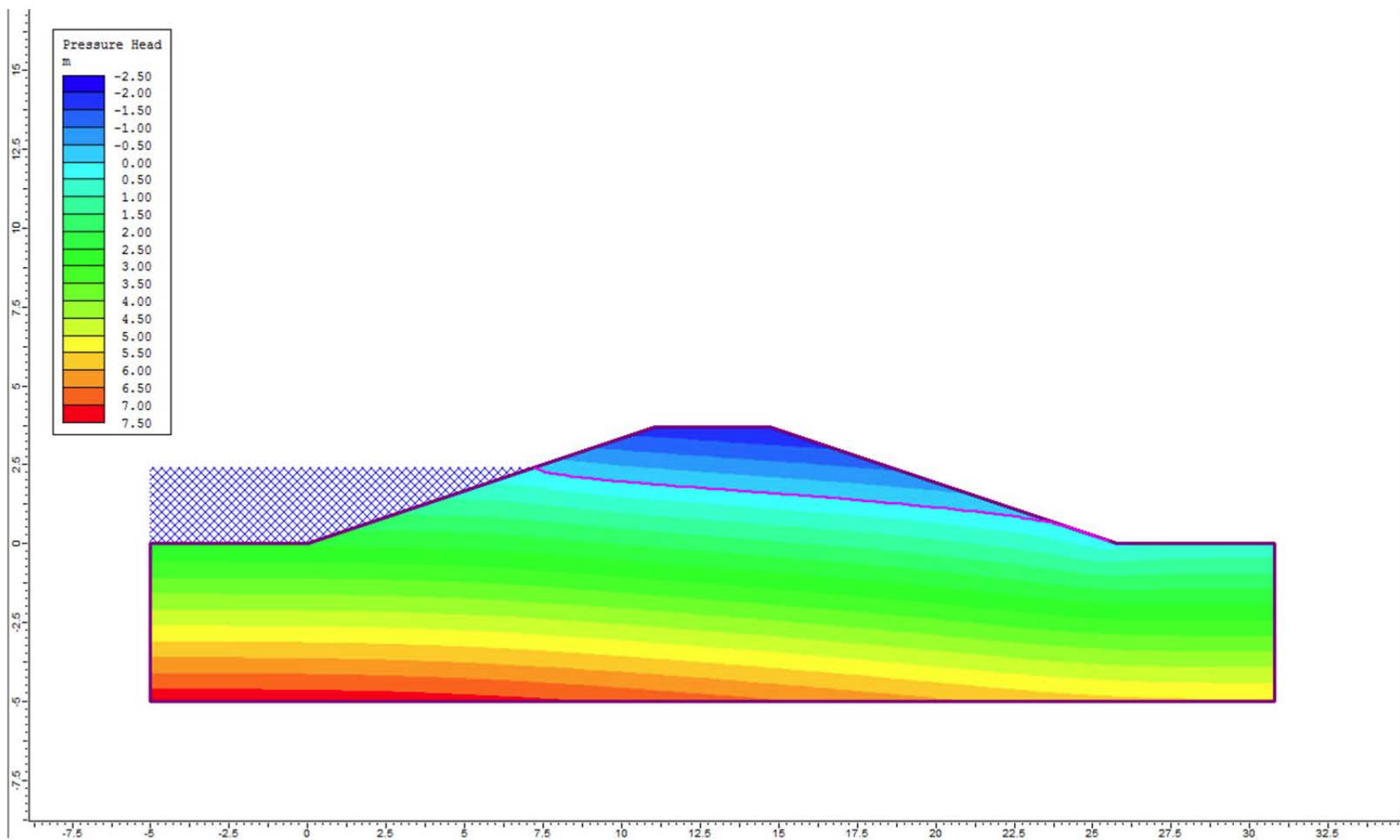
Hazen Method

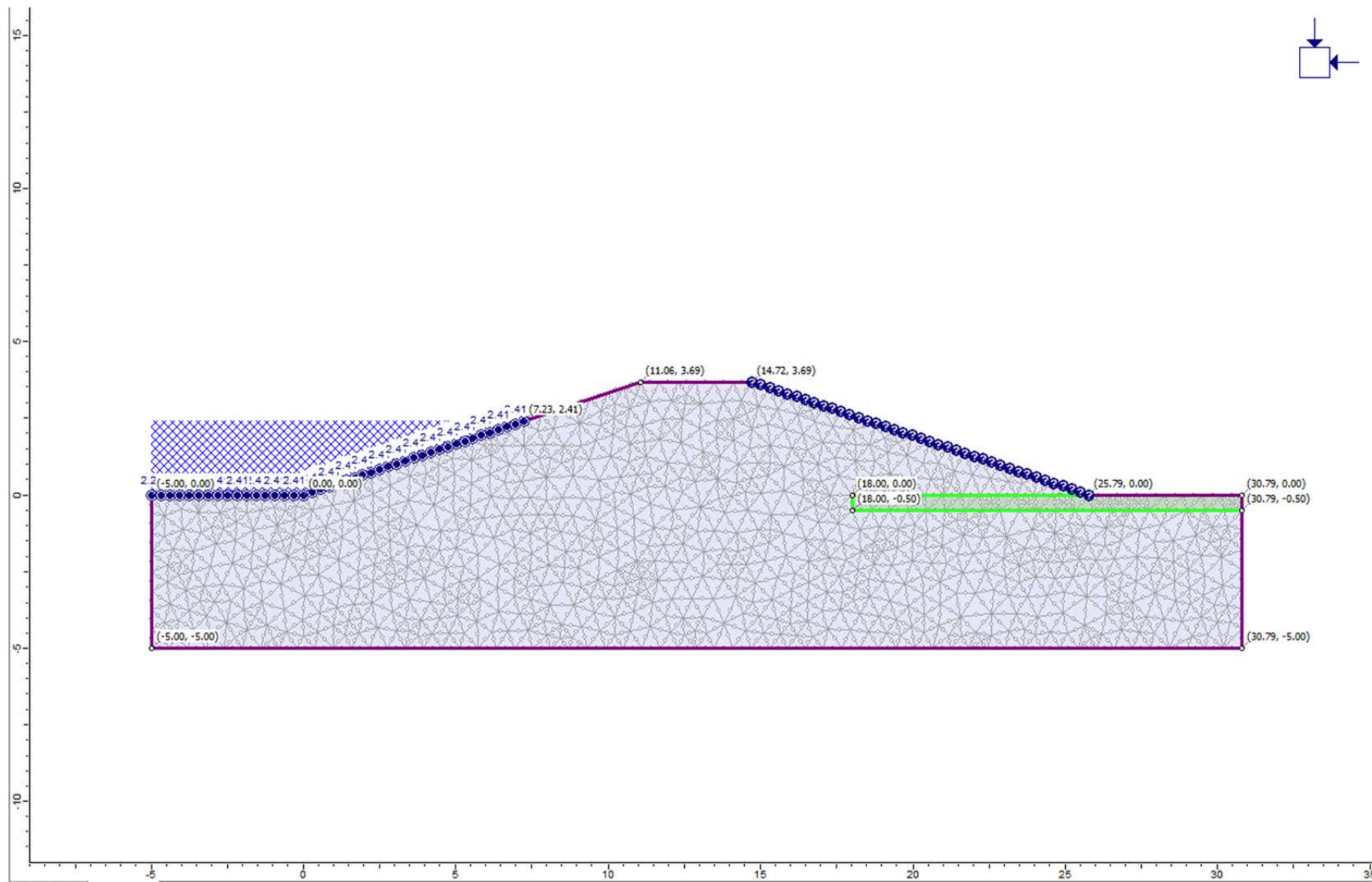
$$K = c * (d_{10})^2 \quad c = 1.1$$

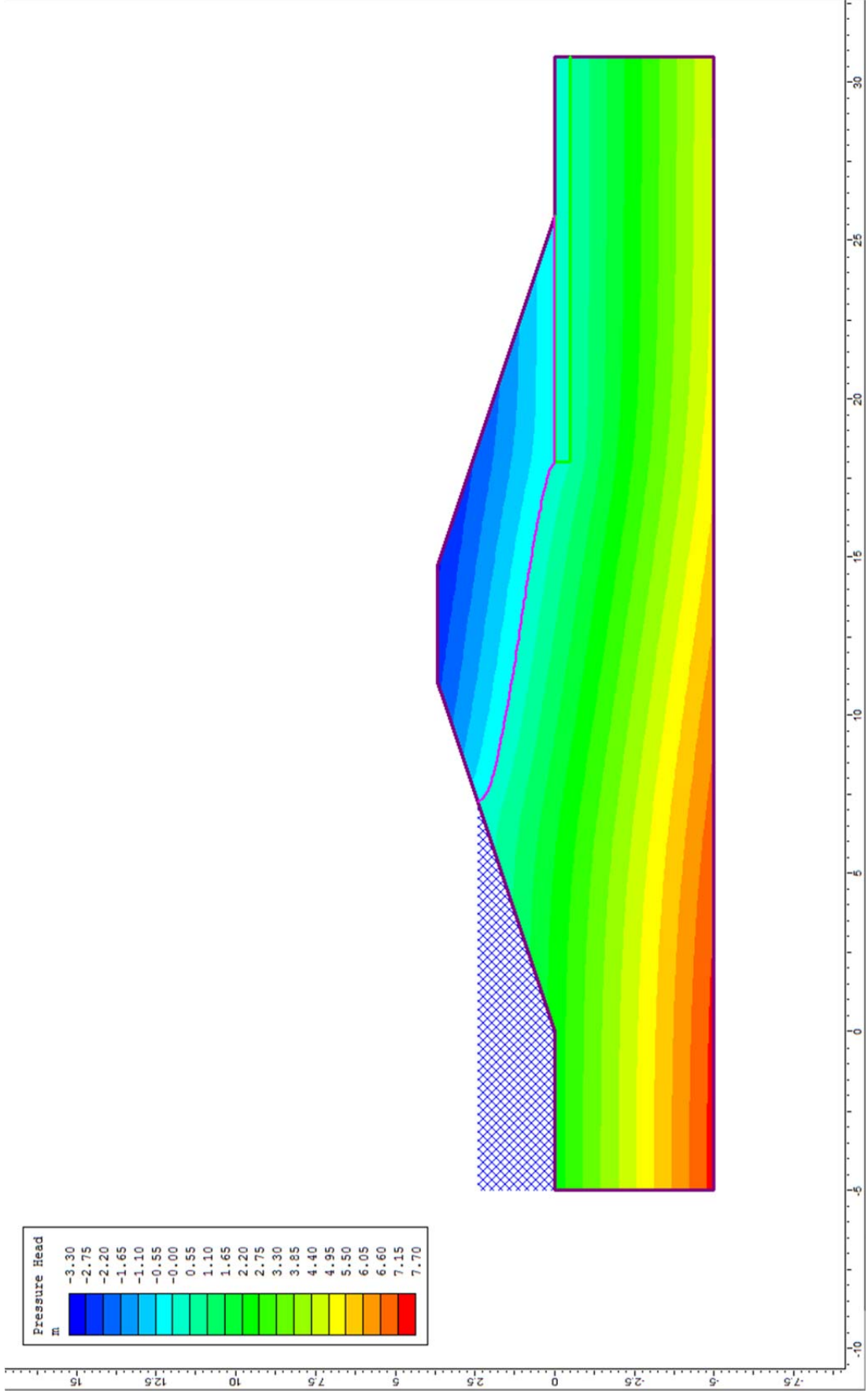
| Sample | cm/sec | ln(K) |
|-------------|-------------|-------------|
| 1 | 2.47500E-06 | -12.9092702 |
| 2 | 1.84910E-05 | -10.8982264 |
| 3 | 1.45475E-06 | -13.4406765 |
| 4 | 3.17900E-06 | -12.6589439 |
| 5 | 8.91000E-05 | -9.32575122 |
| 6 | 4.62275E-04 | -7.67935061 |
| sum ln(K) = | | -66.9122188 |

Geometric Avg. K (cm/sec)=
1.4346E-05

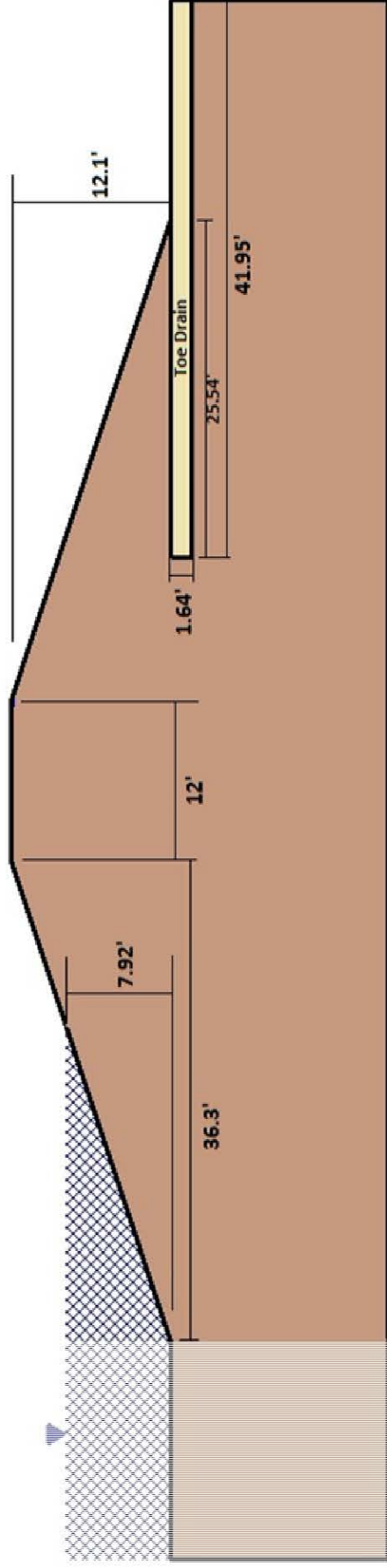








Appendix F



Volume Borrow Material (per unit foot of levee)

$$V' = \text{Area of levee} - \text{area of toe drain}$$

$$V' = (36.3 * 12.1) + (12.1 * 12) - (1.64 * 41.95)$$

$$V = 515.63 \text{ ft}^2 * \text{ft}$$

Total Levee Length

$$L = \text{Perimeter} - \text{Flood Walls}$$

$$L = (5280 * 2) + (2640 * 2) - (40 * 2)$$

$$L = 15,760 \text{ ft}$$

Total Volume of Earthen material for levee

$$V = \text{Volume per unit foot} * \text{levee length}$$

$$V = (515.63 + 68.8) * 15760$$

$$V = 9.2106 \times 10^6 \text{ ft}^3$$

$$V = 3.4113 \times 10^5 \text{ yd}^3$$

Volume of Toe Drain

$$V = \text{Volume per unit foot (toe drain)} * \text{levee length}$$

$$V = 68.8 * 15760$$

$$V = 1.0843 \times 10^6 \text{ ft}^3$$

$$V = 4.0159 \times 10^4 \text{ yd}^3$$

Volume of Borrow Areas

$$V = (\text{Total Levee Volume} - \text{Toe Drain Volume}) * 125\%$$

$$V = (9.2106 \times 10^6 - 1.0843 \times 10^6) * 125\%$$

$$V = 1.0158 \times 10^7 \text{ ft}^3$$

$$V = 3.7622 \times 10^5 \text{ yd}^3$$

Levee Area

$$A = 84.6 * 15760$$

$$A = 1.3333 \times 10^6 \text{ ft}^2$$

Borrow Area

$$A = 180 * [15760 + (84.6 * 4)]$$

$$A = 2.8976 \times 10^6 \text{ ft}^2$$

Total Area

$$A = 1.3333 \times 10^6 + 2.8976 \times 10^6$$

$$A = 4.2309 \times 10^6 \text{ ft}^2$$

Total Volume to be stripped before construction, top 12" of topsoil will be stripped and stockpiled from the base of the levee and the borrow areas.

$$V = 1 * 4.2309 \times 10^6$$

$$V = 4.2309 \times 10^6 \text{ ft}^3$$

$$V = 1.567 \times 10^5 \text{ yd}^3$$

Area of levee to be seeded

$$A = [38.264 * 2 + 12] * 15760$$

$$A = 1.4 \times 10^6 \text{ ft}^2$$

Area of borrow pit to be seeded

$$A = (30.414 * 2 + 120) * 16098$$

$$A = 2.911 \times 10^6 \text{ ft}^2$$

Total area to be seeded

$$A = 1.4 \times 10^6 + 2.911 \times 10^6$$

$$A = 4.311 \times 10^6 \text{ ft}^2$$

Appendix G

Construction Cost Estimate

| Operation | Daily Output | Unit | Total \$ per unit costs | # of units | Cost |
|---|-------------------------------|---------------|-------------------------|---------------------------|-------------------|
| Stripping topsoil and stockpiling with 200 H.P. dozer | 2300 | C.Y. | \$0.61 | 156700 | \$95,587.00 |
| Lawn Bed Preparation, 50' topsoil haul, 12" deep, 200 H.P. dozer | 2660 | C.Y. | \$0.52 | 160000 | \$83,200.00 |
| Seeding Grass, Slope Mix, Hydro or air seeding with mulch and fertilizer | 80 | M.S.F | \$49.50 | 4311 | \$213,394.50 |
| | | | | | |
| | <u>Equipment</u> | <u>Number</u> | <u>Cost per week</u> | <u>Crew Cost Per Week</u> | <u># of weeks</u> |
| Borrow Pit/Levee Construction | | | | | |
| | Loading Tractor, 6 C.Y bucket | 10 | \$2,900.00 | \$4,430.80 | 8 |
| | Tandem Roller, 8 ton | 5 | \$800.00 | \$229.10 | 8 |
| | Dozer 75 H.P. | 5 | \$1,000.00 | \$1,424.50 | 8 |
| Toe Drain Borrow Pit/Levee Construction | | | | | |
| | Loading Tractor, 6 C.Y bucket | 1 | \$2,900.00 | \$4,430.80 | 2 |
| | Dump Truck, 35 ton | 11 | \$3,770.00 | \$5,020.00 | 2 |
| | Dozer 75 H.P. | 2 | \$1,000.00 | \$1,424.50 | 2 |
| | | | | | \$1,334,529.10 |
| Assuming Inflation and Contingency cost of 25% gives a total estimate of | | | | | \$1,668,161.38 |

Construction Equipment Calculations

Borrow Pit/Levee Construction

Need to move $3.7622 \times 10^5 \text{ yd}^3$.

Use common-sized payloader tractor with a bucket size of 6 yd^3 to excavate the soil from the borrow pit and haul to the levee where dozers will level it out and tandem rollers will compact it.

Assume 120 yd^3 can be moved per hour per tractor.

Each tractor will move 960 yd^3 per day and 4800 yd^3 per week.

This results in the need of 10 tractors for a work time of 8 weeks.

Toe Drain/Toe Drain Construction/Hauling from borrow area

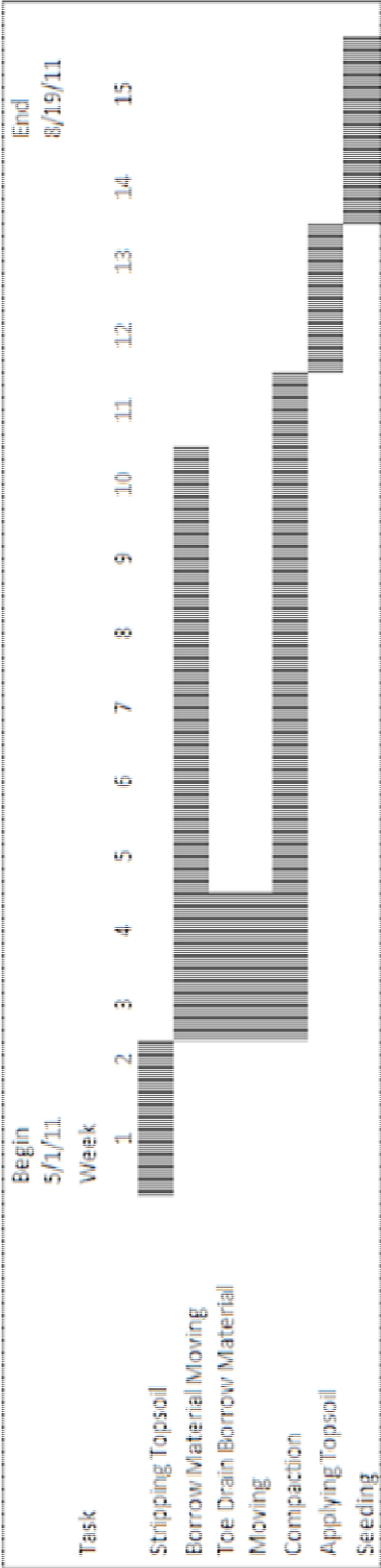
Need to move $4.0159 \times 10^4 \text{ yd}^3$.

The toe drain construction is also going to use a 6 yd^3 tractor to load dump trucks that will haul the material approximately 2 miles to the levee. The trucks will dump the drain material and dozers will level it out. The round trip time was estimated to be 30 minutes.

The R.S. Means books states that the 6 yd^3 tractor can load trucks at a rate of 510 yd^3 per hour, which is 4080 yd^3 per day and $20,400 \text{ yd}^3$ per week. This results in the need of only one tractor for a work time of 2 weeks.

To haul the amount of soil that the tractor can load 11 trucks with a load capacity of 35 tons will be needed for the two work weeks. A 35 ton dump truck can hold 24 yd^3 with the assumed density of approximately 1.5 tons per yd^3 .

Construction Schedule



Appendix I



View of bore hole (B-1) looking West.



View of bore hole (B-1) looking South.



View of the ground at the bore hole (B-1) location.



View of the Eastern half of the proposed site from the Southeast corner.



View of proposed site from the Northwest corner looking East.

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